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DESIGN CONCEPT INVESTIGATION TO MINIMIZE COSTS OF A HYPERVELOCITY TRACK

VON KÁRMÁN GAS DYNAMICS FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
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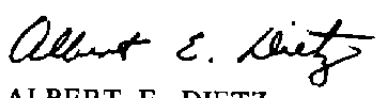

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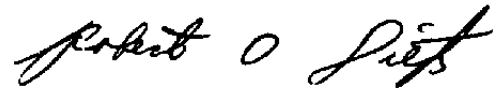

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Typical sections of a prototype hypervelocity track installed in a thin-wall tube for an ablation/erosion chamber was designed, fabricated, and tested as a part of an overall cost reduction study for a "Proposed Reentry Vehicle Ground Test Facility." An estimated cost savings of 40 to 50 percent may be realized utilizing test results obtained in the present investigation. The original cost estimate was based on conventional and proved

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20. ABSTRACT (Continued)

concepts for maintaining rail position and straightness which depends on heavy wall tubes with rails fully supported over their full length. The reduced cost concept utilizes a thin-wall vessel with the rails simply supported near the connecting flanges only. Rail alignment and displacement measurements were obtained under varying conditions that would occur in actual operation of such a facility.

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PREFACE

The work reported herein was conducted at the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC) under Program Element 65807F. The results were obtained by ARO, Inc., AEDC Division (a Sverdrup Corporation Company), operating contractor for the AEDC, AFSC, Arnold Air Force Station, Tennessee. The work was done under ARO Project No. V31S-04A. The author of this report was George W. Hyslip, ARO, Inc. The data analysis was completed on March 26, 1976, and the manuscript (ARO Control Number ARO-VKF-TR-76-87) was submitted for publication on August 11, 1976.

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1.0 INTRODUCTION

A test program was conducted as a part of an overall cost reduction study for a "Proposed Reentry Vehicle Ground Test Facility" with the basic concept as shown in Fig. 1. The facility will be used to test models subjected to various environments and conditions as they travel down range through a preconditioning chamber, an ablation/erosion chamber, and into a free-flight chamber or a model recovery tube. The model will be guided by four rails except in the free-flight chamber during free-flight testing.

In this test program, the ablation/erosion chamber was examined because its length makes it an item for which the design approach for rail support, fabrication techniques, and utilization of material to maintain acceptable rail support, fabrication techniques, and utilization of material to maintain acceptable rail position and alignment requirements will greatly influence the overall facility cost. Component lengths and diameters shown in Fig. 1 have not been finalized; however, they are assumed to be reasonable for the proposed facility.

The original cost estimate of $13,565,000 for the ablation/erosion chamber was based on conventional and proved design concepts for maintaining rail position and straightness. A conventional approach would depend on heavy wall tubes to provide the required rail support. Accurately machined, closely spaced supports between the rails and the tube would be required to utilize the tube stiffness (see Fig. 2). Another approach considered would utilize heavy rail supports independently attached to a foundation with a thin-wall tube for environment containment. These conventional concepts although based on proved designs are expensive.

Costs may be reduced substantially if the assumption is made that advanced technology will permit designing for a lower rail load and that acceptable rail alignment can be maintained with lighter weight components with fewer support points. Material cost alone can be substantially reduced if lighter flanges, lighter rail sections, thinner tube walls, and smaller support structures are required. Large savings may also be realized in fabrication cost. The chamber wall can be much thinner if it is not used for rail support. In this case, the tube wall can be sized to contain a vacuum or low positive pressure only and to be relatively free to move without affecting rail alignment.

2.0 TEST OBJECTIVES

This study was made to determine if a cost effective ablation/erosion chamber could be constructed to maintain acceptable rail position and straightness by utilizing a thin tube design in which the rails are supported only at the flanges. A typical segment of

the chamber assembly with rails of two stiffnesses was fabricated and tested to determine the following:

1. Variation of rail position, straightness, and joint alignment at atmospheric pressure, vacuum, and 15 psig under the following conditions:

   a. With a sunshade,

   b. With the top portion of the tube assembly heated to simulate a very hot sunny day, with a sunshade (no insulation), and

   c. With the tube insulated, without a sunshade, exposed to the sun.

2. Disturbance of adjacent rail sections when one rail is subjected to transverse static loading.

3. Effect of penetrations on the tube assembly and rail alignment.

4. Repeatability of installation with and without centerline guides.

5. Fabrication and assembly techniques.

3.0 TEST EQUIPMENT

3.1 DESCRIPTION

3.1.1 General Arrangement

A typical erosion chamber segment consisting of two tube assemblies with rails, one tube assembly 10 ft long and the other 9 ft long, was constructed of tubing having an outside diameter of 30 in. and a wall thickness of 0.25 in. The tubes were flanged at each end with internal mounting pads for the rails (see Figs. 3, 4, and 5). The pads were located near the flanges to transfer load directly to the flanges instead of through the thin tube wall. Provision was made to allow the option of center supporting each rail from the tube wall to determine if some rail load could be supported by the tube without affecting rail alignment. A 1-ft-long expansion joint section (one will be required for each 100 ft of ablation/erosion chamber length) was fabricated to duplicate the expansion joint required for the assumed chamber installation. The standard 10-ft-long chamber section, the 9-ft-long section, and the expansion joint were coupled together for the test. End closure flanges with viewing ports and a thrust stand to carry the thrust loads due to

pressure and vacuum were provided. Tube support stands were located at each flange joint (3 places) with provision for axial movement between the tube assemblies and the supports.

Removable centerline guides were attached to the tube support stands for maintaining orientation of the tube assemblies about the longitudinal axis (see Fig. 5).

Internal and external stops (see Fig. 5) were provided to limit the expansion joint movement to the maximum amount that would be experienced in the full-length chamber installation. This duplicates the maximum end load on the tube assemblies in a full-length installation. The tube assemblies, expansion joint section, and support stands were designed to utilize a minimum of material with simplified fabrication techniques for maximum cost reduction.

3.1.2 Rails

The rail size was limited to a shape that would fit into a 5- by 10-in. rectangular area. The maximum rail height of 10 in. was defined by the selected tube diameter of 30 in. and model diameter of 8 in. Experience with other installations indicated that a nominal width of 5 in. reduced to approximately 1 in. at the model contact surface would not produce excessive interference with the flow over the model and would provide adequate area for viewing. A nominal tube diameter of 30 in. was dictated by a ratio of test chamber diameter to model diameter which, based on previous experience, would ensure that wall effects would not interfere with the flow over the model. Several beam cross sections (shown in Fig. 6) were considered for rails before two were chosen for testing. The choice of the 25.12-lb/ft beam (beam 5, Fig. 6) was based on the low deflection for the weight of material using a standard I-beam shape. The shape was easy to fabricate and could be readily rolled with modified beam rolling equipment in quantities required for the full-length track.

The 48.7-lb/ft rail (beam 12, Fig. 6) was designed to minimize deflection with a beam weight approximately twice that of the lighter weight beam (25.12 lb/ft) being investigated. The beam geometry was established by distributing the area for minimum deflection for the weight of material considering ease of manufacture of the special I-beam shape either by fabrication or by rolling with modified beam rolling equipment. Again, the size would fit into the desired 5- by 10-in. rectangular area. Material for all rails was low carbon steel (ASTM-A-36-62T).

When the 48.7-lb/ft rails (Sections 5.7 and 5.8) were installed, the only rails exchanged were number 9 for number 6 and number 10 for number 5 in the 10-ft-long tube assembly.

All other rails were left in place. To replace the rails, the assembly was removed from the test assembly, taken to the shop, rails exchanged, returned and reinstalled.

3.1.3 Insulation

The tube assemblies were wrapped between the flanges with a 3.5-in.-thick layer of fiber glass insulation as shown in Fig. 7 (U = 0.091 Btu hr/ft^2/°F), in the cases for which measurements were obtained for insulated conditions.

3.1.4 Rail Loading Device

The rail loading device consisted of a jacking block between the upper left and lower right rails attached to rods extending through the tube wall and anchored to a jack stand on the foundation as shown in Fig. 8. Small hydraulic jacks mounted on the jacking block and jacked separately against each rail provided the required rail load. The loading device was moved and installed at three different locations (Stations 30, 60, and 90, see Fig. 5 for station locations).

3.1.5 Sunshade and Heaters

A sunshade was installed over the complete test assembly as shown in Fig. 9 and remained during all the testing except for the portion in which the tubes were insulated. Twelve 750-w (9,000 w total) electric strip heaters were installed on the outside of the tube assembly (on the top portion) to obtain a rough simulation of sunny day conditions. The strip heaters covered an area approximately 3 in. wide by 100 in. long on each tube section. The flanges were not heated. Before the sunshade was installed, the temperature difference between the top and bottom of the tube assemblies was observed during a day of hot sunshine (90 to 94°F) and found to be approximately 30°F. This temperature difference was maintained during temperature testing. Iron-constantan thermocouples were installed at the top, side, and bottom of the tube and centered between tube flanges (Stations 60 and 114). A Leeds and Northrup Speedmax Recorder was used to monitor and record shell temperatures.

3.2 RAIL FABRICATION TOLERANCES

The rails were fabricated by welding standard low carbon steel beam sections and plate together (ASTM-A36-62T). The steps were (1) welding, (2) stress relieving, and (3) grinding. The stress relief was as follows: Heat to 1,200°F, soak for two hr per in. of thickness, and furnace cool with a heating rate less than 400°F per hr and a cooling rate less than 200°F per hr. The rails were measured for straightness prior to installation in

the tube assemblies. All rails were straight within 0.002 in. except for one which was straight within 0.008 in. Soon after testing, the rails were removed and remeasured (see Section 5.1).

4.0 MEASUREMENT EQUIPMENT AND METHOD

4.1 SCOPE, TARGET, AND TAPE

The scope used was a Keuffel and Esser (K&E) alignment telescope, catalog number 71220, mounted on a Brunson Model 370 collimating test stand. The reticle in the scope was located approximately 11 ft, 1 in. from station 0 (end of rail nearest scope). The instrument accuracy is ±0.002 in. at 40 ft and ±0.004 in. at 80 ft per K&E specifications.

A target was mounted on a specially designed holder which was spring loaded against two rails simultaneously, either the lower or upper rails. The target and target holder are shown in Fig. 10. Packing glands in the test assembly end flanges were provided for the target pull-wire. A steel measuring tape was used to locate measuring stations.

4.2 PROCEDURE FOR MEASUREMENTS

Prior to data taking, the telescope centerline was aligned to the centerline of the test assembly. The test assembly centerline was defined as a line established with the target set at stations 4.25 and 231.00 (limits of travel of target due to end flanges). Station 4.25 is over a pivot point, while station 231.00 is 7.33 in. from a pivot point. Since the rails are rotated 45 deg from the vertical and horizontal centerlines of the vessel, the telescope was also rotated so that the telescope centerlines would be parallel to the rail surfaces.

Measurements were taken by pulling the target from station to station through the vessel with the target position being read as (+) (above centerline of telescope) and (-) (below centerline). A plus (+) reading indicated the rail was high, and a minus (-) reading indicated the rail was low. After the measurements were taken at all stations on the lower or upper rails, the target holder was rotated, and the opposite rails were measured.

The stations were located using a steel measuring tape to measure pull-wire lengths extending outside the flanges.

4.3 ACCURACY OF MEASUREMENTS

The accuracy of measurements was dependent on the telescope accuracy, environmental conditions, and the telescope operator. The distance from the telescope

to the target varied from approximately 11 to 31 ft. Recorded measurements included the telescope inaccuracy, rail straightness, machining deviations, and rail deadweight deflection in addition to the deflections created by the condition being investigated.

4.4 METHOD OF EVALUATION

All measurements obtained during this investigation are recorded in Appendix A, and an examination of the rail measurements, except for the rail transverse loading measurements, indicated that distortion of the rails between support points (bowing and twisting) greater than the error level of the measurements did not occur (see Fig. A-2 for a representative plot of measurements taken). Therefore, movements of the rails at the rail support points (Stations 4.25, 115.71, 124.25, and 223.67) are considered here to define the total movement of the rails as installed and supported in the prototype chamber. The rail support points are pivot points of the simply supported rails.

Although the rails were installed perfectly centered to the flanges in the shop, they became misaligned during the initial test installation. This misalignment constantly changed during testing, as a result of stress relief from aging and load cycling, atmospheric temperature changes, and the inability to accurately adjust the supports at initial installation. This initial misalignment was such to either increase or decrease the actual measured step between adjoining rails depending on direction of movement. The recorded measurements in Appendix A include the initial misalignment at the reference condition.

Rail steps, or joint discontinuities, between rail surfaces across the joints are those actually measured unless noted "corrected" which indicates that an adjustment was made to the measurement to evaluate the misalignment of the rails had they been perfectly aligned at the start of the test. Joint misalignment did not affect the displacement measurements.

Consistent with comments above, only the measurements at the support points were used in evaluating the effect of the various conditions, and these data are presented in Figs. 11 through 26.

5.0 MEASUREMENTS OF DEFLECTIONS AND MOVEMENTS

5.1 DIMENSIONAL CHANGE OF COMPONENT PARTS AFTER AGING

Table A-1 of Appendix A presents measurements of the straightness of all rails taken before installation and again after conclusion of testing approximately three months later. Comparison of these before and after measurements indicates that the rails do lose

straightness as they age. This condition can result from the relaxation of internal stresses due to room temperature creep.

One could expect similar dimensional changes in the tube assemblies since they were constructed of similar materials with no post-weld heat treatment. The validity of this logic was supported by the following: The rails were installed in the tube assemblies with the distance between adjacent rail faces accurately set to 8.000 in. This distance was remeasured during testing of the thermally insulated tube assembly at atmospheric pressure and at a temperature near that of the shop during installation of the rails in the tube. The changes in rail position resulting from approximately three weeks of aging are illustrated in Fig. 11.

The rail and tube assemblies were fabricated from mild carbon steel shapes joined by welding. The rails were stress relieved as described in Section 3.2, while all other parts were left in the as-welded condition. The stress relieving process did not prevent changes in straightness of the rails as they aged. The tube assemblies were not heat treated because a considerable cost reduction could be made on the production parts if this test had shown satisfactory dimensional stability without heat treatment.

5.2 REPEATABILITY (ATMOSPHERIC PRESSURE)

A 10-ft section of tube assembly including rails was installed with centerline guides between the tube and its support stands, and measurements were made to establish rail surface positions. This tube assembly was then removed and the entire procedure repeated for a total of three times. The measurements indicate that repeatability of rail position following removal and reinstallation of the tube assembly on its support was good when using centerline guides. Figure 12 indicates that the maximum difference in position of any rail at its support point was 0.011 in.

The centerline guides were removed, and the procedure described above was repeated. Rail measurements indicated that the assembly did not repeat position quite as well as with the centerline guides. Figure 13 indicates that the rail position difference increased to a maximum of 0.014 in.

All subsequent testing was done using the centerline guides.

5.3 MODIFIED I-RAIL, 25.12 LB/FT

This rail and tube configuration was tested under atmospheric, 15 psig, and vacuum conditions with and without heating while protected by a sunshade. The tops of the tube

assemblies were heated to produce a temperature gradient of approximately 30°F from top to bottom.

Measured rail displacements at 15 psig and vacuum relative to the position at atmospheric pressure without heating are shown in Fig. 14. Figure 15 shows rail displacements at atmospheric pressure, 15 psig, and vacuum with heat applied relative to the position at atmospheric pressure without heating. The maximum indicated steps across the joint between adjoining rail surfaces shown in these plots are 0.019 in. (corrected, see Section 4.4) with heat applied and 0.017 in. (corrected) without heat. The maximum steps actually measured were 0.018 in. with heating and 0.013 in. without heating.

5.4 MODIFIED I-RAIL, 25.12 LB/FT SUPPORTED AT CENTER BY WALL OF TUBE

The rail and tube configuration and test procedure duplicate those described in Section 5.3 except that an additional rail support, at mid-span of the rail and attached to the wall, was installed.

Measured rail displacements at 15 psig and vacuum relative to the position at atmospheric pressure are shown in Fig. 16. Figure 17 shows rail displacements at the three pressure conditions with heat applied relative to the position at atmospheric pressure without heating. The maximum indicated steps across the joint between adjoining rail surfaces shown in the plots are 0.025 in. (corrected) with heat applied and 0.018 in. (corrected) without heat. The maximum steps actually measured were 0.018 in. with heating and 0.014 in. without heating.

5.5 MODIFIED I-RAIL, 25.12 LB/FT WITH TUBE INSULATED

The rail and tube configuration and test procedure were similar to those described in Section 5.3. Tests were made under atmospheric, 15 psig, and vacuum conditions after installing a 3.5-in. thickness of fiber glass thermal insulation on the tube assemblies (see Fig. 7). Tests were made on a sunny day without a sunshade being used.

Measured rail displacements at 15 psig and vacuum relative to the position at atmospheric pressure are shown in Fig. 18. The maximum indicated step across the joint between adjoining rail surfaces shown in the plot is 0.006 in. (corrected). The maximum step actually measured was 0.013 in.

This was the best rail and tube configuration tested as determined by minimum rail displacements under all pressure conditions.

5.6 MODIFIED I-RAIL, 25.12 LB/FT SUPPORTED AT CENTER BY WALL OF TUBE WITH TUBE INSULATED

The rail and tube configuration and test procedure duplicate those of section 5.5, except that an additional rail support, at mid-span of the rail and attached to the tube wall, was installed.

Measured rail displacements at 15 psig and vacuum relative to position at atmospheric pressure are shown on Fig. 19. The maximum indicated step across the joint between adjoining rail surfaces shown in the plot is 0.007 in. (corrected). The maximum step actually measured was 0.012 in.

5.7 SPECIAL I-SHAPE, 48.7 LB/FT

The rail and tube configuration and the test procedure were similar to those described in Section 5.3. Two of the 25.12-lb/ft rails, numbers 5 and 6, were replaced with 48.7-lb/ft rails, numbers 10 and 9, respectively. The rail numbering and location scheme is presented in Fig. A-1 of the Appendix A. Measurements were made under atmospheric, 15 psig, and vacuum conditions with sunshade protection. The tops of the tube assemblies were heated to produce a temperature gradient of approximately 30°F top to bottom.

Measured rail displacements at 15 psig and vacuum relative to the position at atmospheric pressure without heating are shown in Fig. 20. Figure 21 shows rail displacements at atmospheric pressure, 15 psig, and vacuum with heat applied relative to the position at atmospheric pressure without heating. The maximum indicated steps across the joint between adjoining rail surfaces shown in the plots are 0.014 in. (corrected) with heat applied and 0.009 in. (corrected) without heat. The maximum steps actually measured were 0.014 in. with heating and 0.012 in. without heating.

5.8 SPECIAL I-SHAPE, 48.7 LB/FT SUPPORTED AT CENTER BY WALL OF TUBE

The rail and tube configuration and test procedure duplicate those described in Section 5.7, except that an additional rail support attached to the tube wall at midspan of each rail was installed.

Measured rail displacements at 15 psig and vacuum relative to the position at atmospheric pressure are shown in Fig. 22. Figure 23 shows rail displacements at the three pressure conditions with heat applied relative to the position at atmospheric pressure without heating. The maximum indicated steps across the joint between adjoining rail surfaces shown in the plots are 0.013 in. (corrected) with heat applied and 0.006 in.

(corrected) without heat. The maximum steps actually measured were 0.008 in. with heating and 0.016 in. without heating.

5.9 EFFECTS OF TUBE PENETRATION

Penetrations, or openings, were added to the tube assembly as shown in Fig. 24. Except for these penetrations, the rail and tube configuration and test pressures were unchanged from those in Section 5.7. Tube heating was not used in this test.

Measured rail displacements at 15 psig and vacuum relative to the position at atmospheric pressure are shown in Fig. 25. The maximum indicated step across the joint between adjoining rail surfaces shown in the plots is 0.006 in. (corrected). The maximum step actually measured was 0.013 in.

5.10 RAIL LOADING (ATMOSPHERIC PRESSURE)

5.10.1 25.12-lb/ft Rail

This rail and tube configuration was similar to that described in Section 5.3 It consisted of the tube assemblies with a complete set of 25.12-lb/ft rails and shell penetrations. Provision was made for loading one pair of opposing rails, consisting of the upper left (number 5) and lower right (number 6). A single force of 6,400 lb was applied sequentially to rails number 5 and 6 at stations 30, 60, and 90.

The 6,400 lbf simulated a predetermined reasonable maximum rail load for a reentry vehicle test facility of this size. This value was obtained from a flexible model loading analysis, which indicated that thick-wall Lexan® projectiles can experience acceleration loads of about an order of magnitude less than a rigid body, if the dynamic design is appropriate. This analysis yields a load of 6,400 lb for a typical 8-in. projectile traversing a 0.001-in./ft curvature at 18,000 ft/sec.

Rail position measurements were made immediately after either loading or unloading a rail to minimize the possible effect of temperature changes.

Measured rail displacements of the loaded rail and its abutting rail produced by each of the six positions of load are shown in Fig. 26. The maximum indicated step across the joint between adjoining rail surfaces shown in the plots is 0.012 in. (corrected). The maximum step actually measured was 0.019 in.

5.10.2 48.7-lb/ft Rail

Two of the 25.12-lb/ft rails, numbers 5 and 6, were replaced with 48.7-lb/ft rails numbers 10 and 9, respectively. All rail loading and measurement procedures described in Section 5.10.1 were repeated.

Measured rail displacements of the loaded rail and its abutting rail produced by each of the six positions of load are shown in Fig. 26. The maximum indicated step across the joint between adjoining rail surfaces shown in the plot is 0.012 in. (corrected). The maximum step actually measured was 0.023 in.

Rail displacement measured at mid-span points and corrected for support point displacements were not greater than the calculated values.

6.0 COMPARISON OF PERFORMANCE

A summary of test conditions and results is shown in Table 1.

The repeatability of rail position when removing and installing a tube assembly with a V-type of support was improved by the addition of a centerline guide between the tube and its support stand as indicated by the measurements discussed in Section 5.2.

The measurements for the modified I-rail, 25.12 lb/ft, with the tube insulated as described in Section 5.5, indicated that changes in pressure from atmospheric to either vacuum or 15 psig has a small effect on rail position since rail displacements ranged from 0.00 to 0.010 in. maximum. The same rail and tube configuration protected by a sun shield instead of insulation, (Section 5.3) had rail displacements ranging from 0.00 to 0.037 maximum. When the tops of the tube assemblies were heated to produce a 30°F temperature gradient from top to bottom, the rail displacements ranged from 0.000 to 0.012 in. maximum at atmospheric pressure, and 0.007 in. minimum to greater than 0.053 in. maximum at vacuum and 15 psig. Comparison of the above displacements indicates that 0.010 in. is the maximum displacement resulting from the pressure changes with the assemblies insulated. However, when the assemblies were heated much greater displacements for the same pressure changes were noted (see Fig. 15). Apparently an unstable condition in the tube assemblies develops upon heating causing greater displacements for all the heated configurations.

It is evident that the thermal insulation minimizes temperature gradients within the tube assembly and greatly reduces the attendant rail displacements.

The effect of a center support can be evaluated using the configurations described in Sections 5.5 and 5.6 since the insulation essentially eliminates distortion caused by

temperature gradients. The change in rail displacements caused by center supports ranges from 0.00 to 0.016 in. at vacuum and from 0.00 to 0.018 in. for 15 psig. This indicates that various pressure conditions cause the tube to deflect which causes the center support and rail to move.

When the special I-shape 48.7-lb/ft rails (Sections 5.7 and 5.8) were installed, the displacements measured did not agree very closely with the previous configuration. The rails in the tube section that were left in place had different displacements than before, even though they were left undisturbed except for the bolting together of the sections. Apparently some strain either existed before the removal of the tube assembly or was induced during the reinstallation due to the flange bolting sequence or an inadequate self-alignment feature on the support stands. Error in flange face squareness to rail axis could also have been a factor.

Rail displacements determined after the penetrations were installed (Section 5.9) were within the same minimum and maximum displacements as shown in Section 5.7 at atmospheric, vacuum, and 15 psig pressures. The addition of the penetration and weld shrinkage caused a noticeable deflection of the tube material toward the tube centerline in the vicinity of the penetration. However, it had little effect on the rails.

The rail displacements at the support points due to rail loading for both the 25.12- and the 48.7-lb/ft rails (Sections 5.10.1 and 5.10.2) had displacements at the pivot points of 0.018 in. or less except for two measurements at station 4.25 with the lower right rail (No. 9) loaded. Since the time span of the measurements virtually eliminated temperature effects, the rail displacements are the combined deflections of rail supports, tube assemblies, flanges, and support stands.

The proposed ablation erosion chamber design concept employs simple pinned and guided-end supports for the rails. Therefore, the exact shape and stiffness of the rails should not greatly influence deflections of the tube or rail support system resulting from temperature and pressure effects on the tube. The comparison of the test data taken with the alternate rail shape installed in the tube supports this comment.

7.0 CONCLUDING REMARKS

The modified I-rail (25.12 lb/ft with insulation and without rail center supports, (Section 5.5) was the best configuration based on minimum rail movement. This result, however, could not be directly traced to the use of this rail configuration rather than the 48.7-lb/ft rail. This configuration with centerline guides had better repeatability than the configuration without centerline guides.

It was found that displacement due to pressure was much greater with the top heated than with insulation. Apparently an unstable condition was created in the tube assemblies when heat was applied.

The tube assembly was distorted slightly near the penetrations when they were welded to the tube. The range of rail displacements prior to penetrations was 0.001 to 0.012 in. compared with 0.000 to 0.019 in. after penetrations were installed. This indicated that the penetrations affected the rail alignment only slightly since the 0.007-in. maximum variation includes measurement inacurracy.

The rail displacements due to rail loadings were 0.018 in. or less except for two data points, which were 0.032 and 0.039 in. Since temperature effects were eliminated, the displacements were due to the deflections of the tube, flanges, and supports.

The measured rail deflections at midspan were not greater than the calculated values.

It was not proved that the 48.7-lb/ft rail offers any advantage over the 25.12-lb/ft rail except in reducing rail deflection between support points when the rail was loaded.

The following facts have been determined based on the testing and study:

1. The rails can be supported by attaching only at each end to the tube flanges.
2. A thin-wall tube can be used satisfactorily.
3. Penetrations can be made in the tube with a small effect on rail alignment.
4. The thin-wall tube cannot be used to support a part of the rail load.
5. Mild steel component parts must be heat treated to eliminate dimensional changes due to aging.
6. The ablation/erosion chamber must be insulated to reduce temperature effects.
7. Tube sections can be fabricated and rails installed in the shop within the accuracy required to obtain interchangeability between sections, with and without penetrations.
8. The assembly must have centerline guides.

Further testing should be conducted to gain additional information on material stability, insulation requirements, support stand requirements, optimum flange and tube

wall thickness, and fabrication and installation techniques. The additional testing should be conducted with an assembly designed with the same concept utilizing the information gained from this test and study. The following changes are recommended:

1. All components of the tube assembly constructed of mild steel should be heat treated using the best known methods available for the type of material being used, to achieve maximum dimensional stability.

2. Only the insulated configuration should be tested with tube assemblies, flanges, and support structure fully insulated to minimize temperature effects.

3. The mounting pads on the support stands should self-align and have height adjustments to eliminate any preloading of the test assembly during installation.

4. Flanges should be bolted together only after installing insulation on the tubes and with mating tubes maintained at or very near the same temperature.

5. Increase flange thickness to decrease the deflection due to rail loadings. However, if at the time of testing information has been gained to indicate that the loads are less than the 6,400 lbf used in this investigation, the flange thickness should be adjusted accordingly.

An estimated cost savings of 40 to 50 per cent over the conventional method may be realized in fabricating an ablation/erosion chamber utilizing the test results obtained in the present investigation.

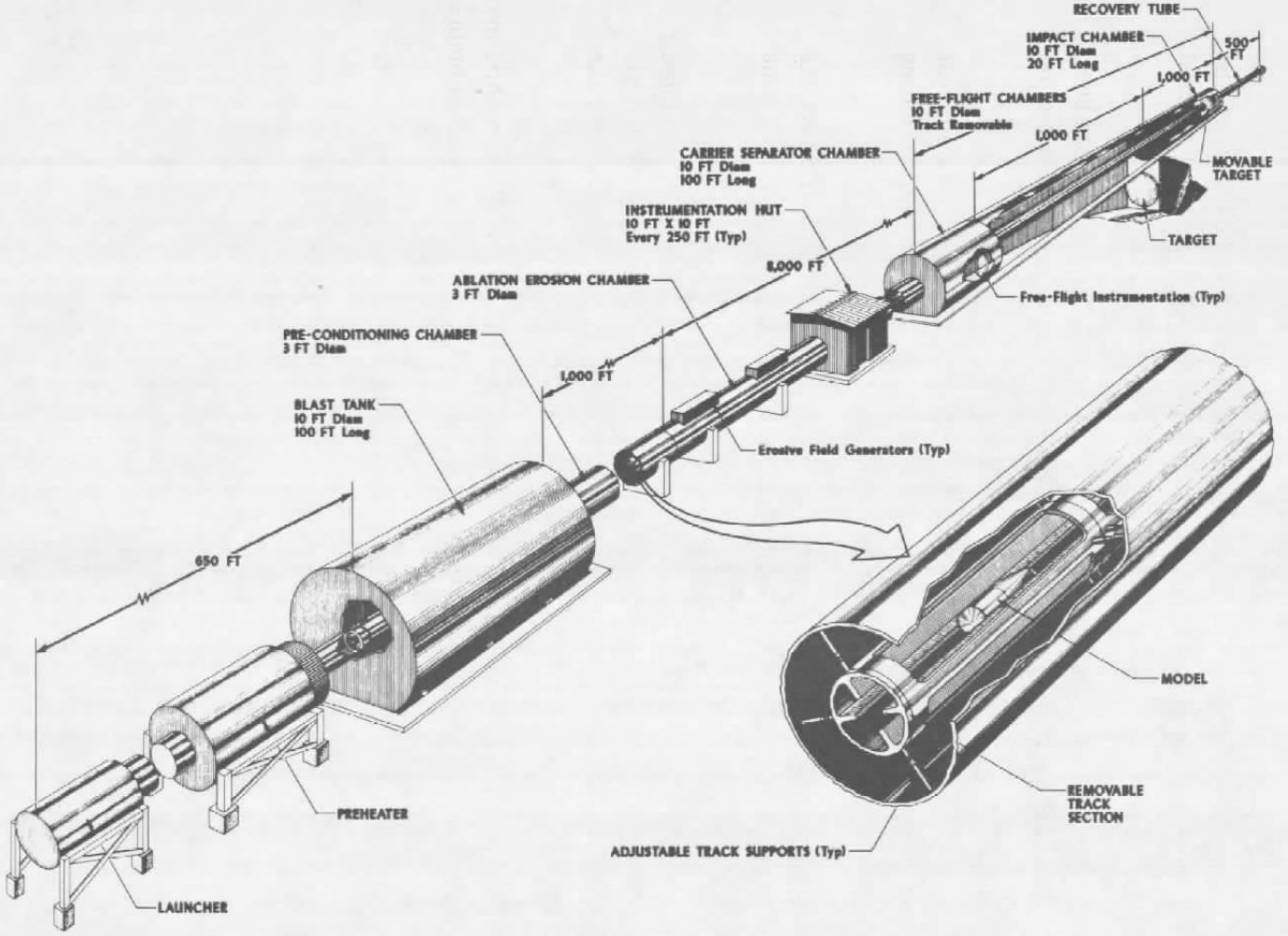


Figure 1. Proposed reentry vehicle ground test facility with 8-in.-diam model.

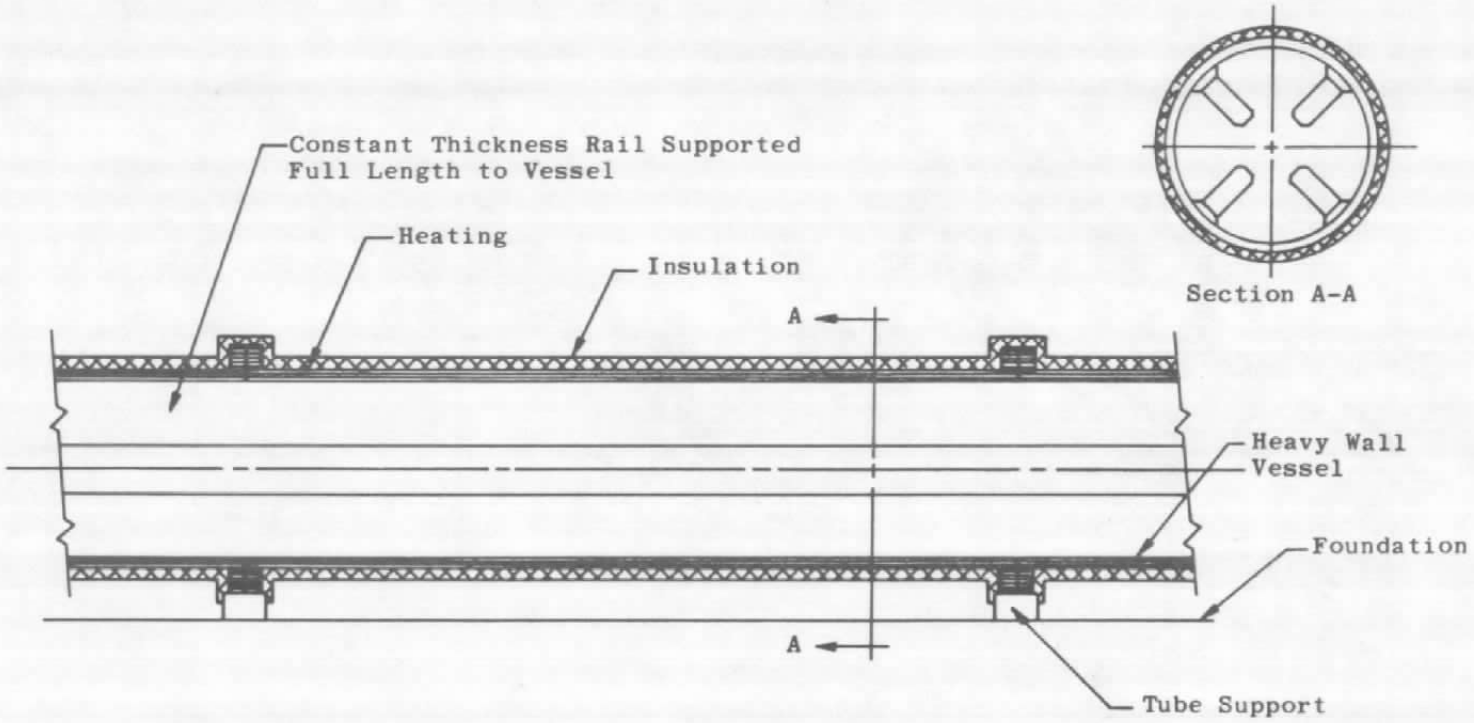


Figure 2. Conventional design.

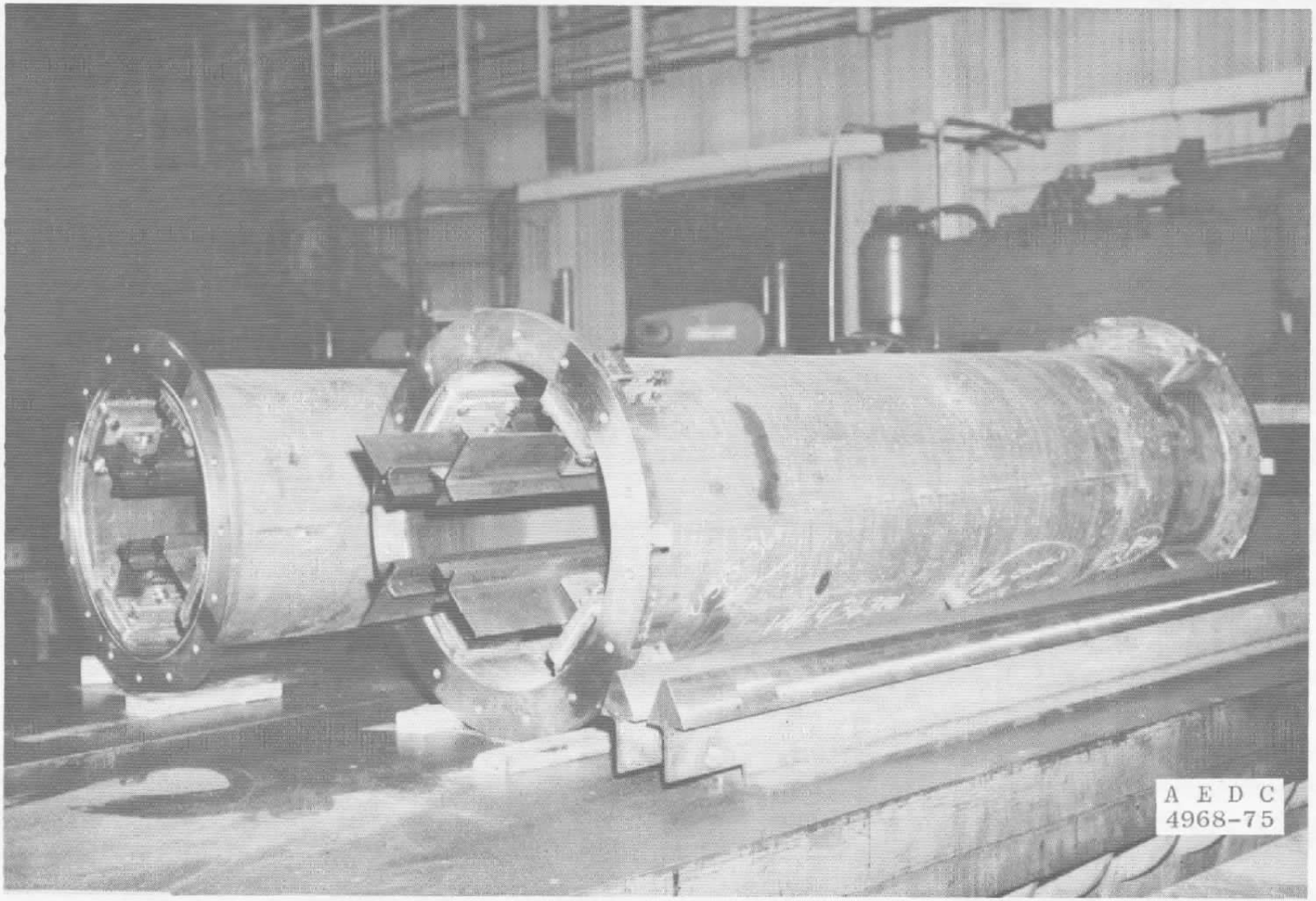


Figure 3. Tube assemblies overall view.

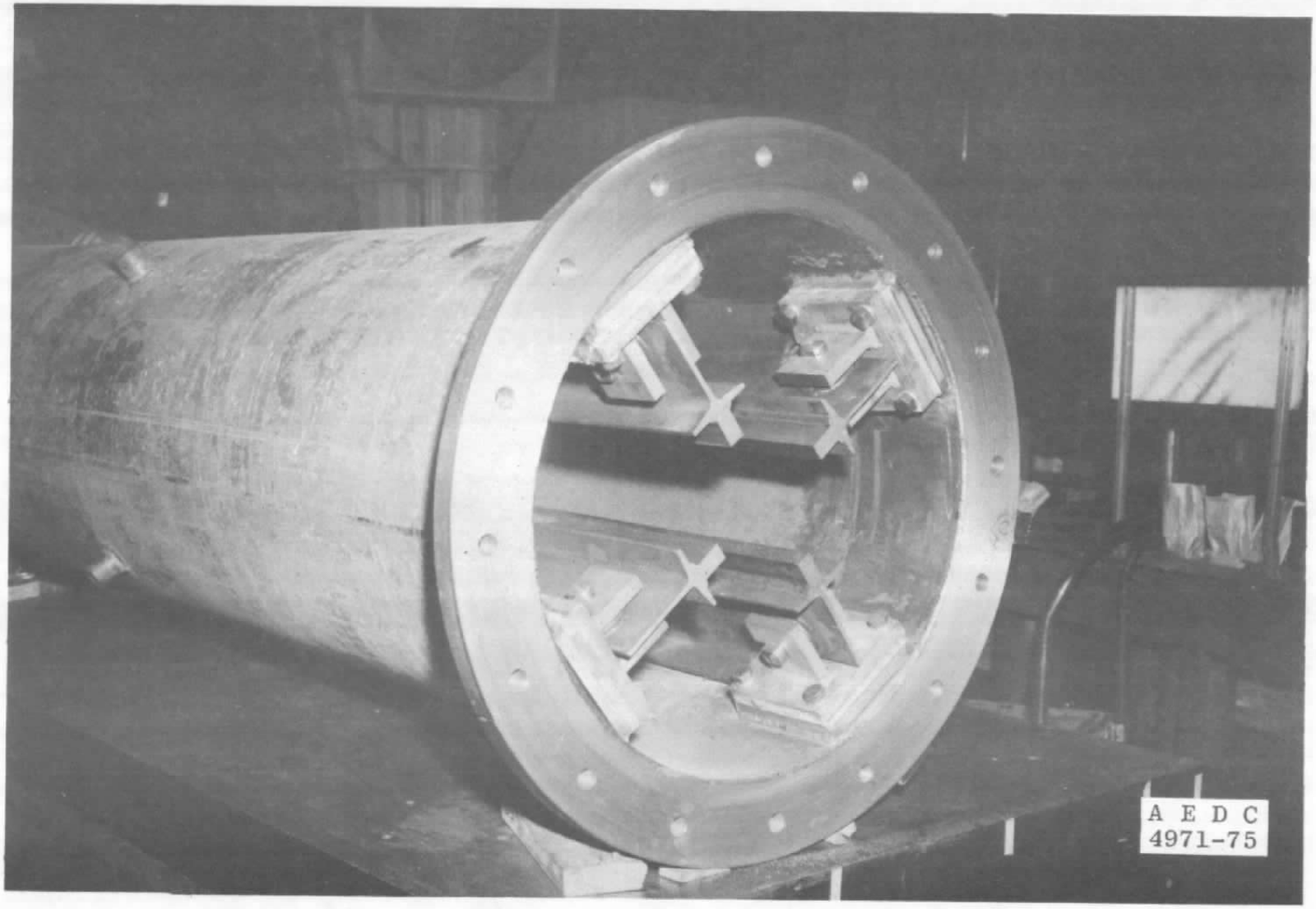


Figure 4. Tube assembly rail support pivots.

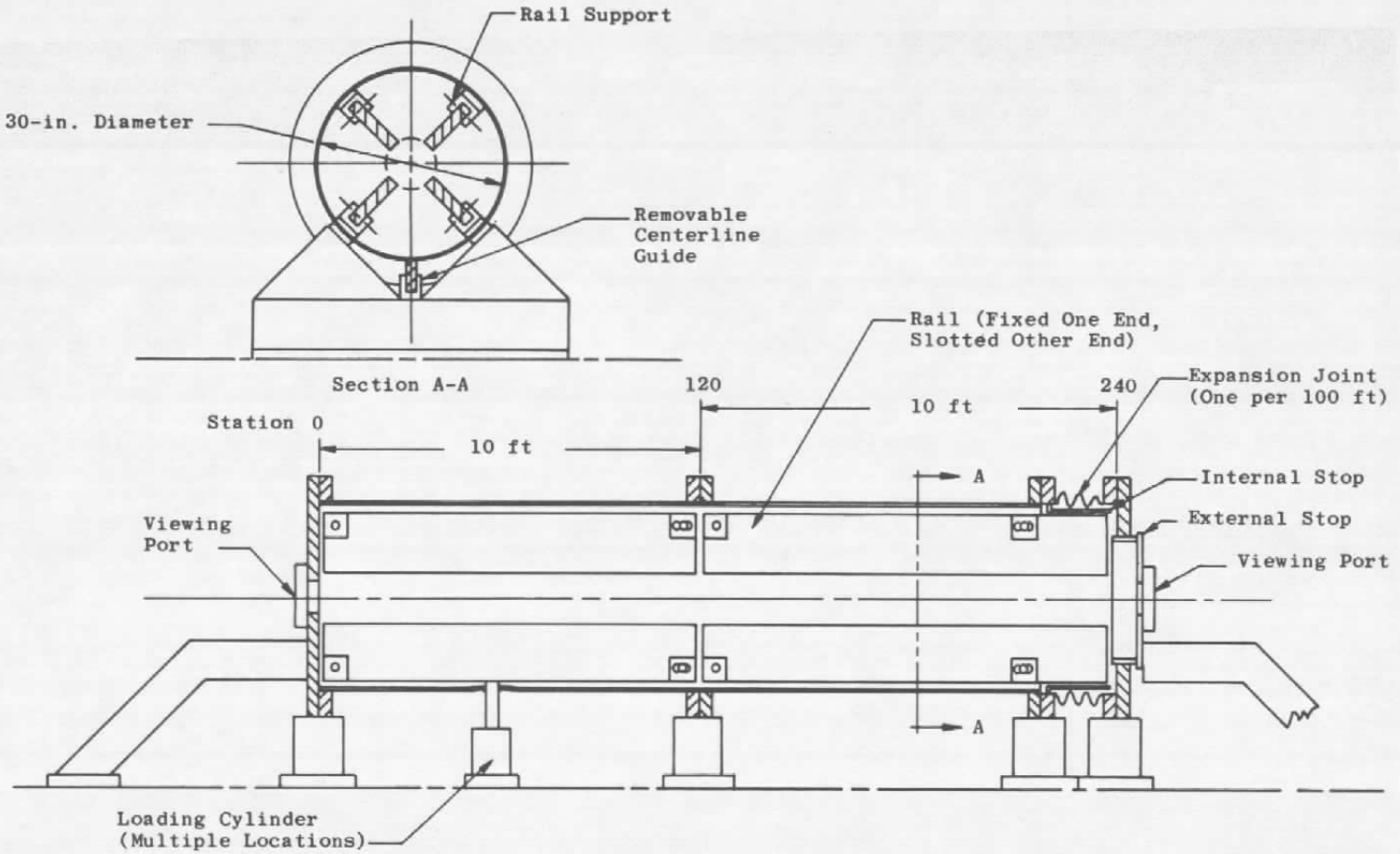
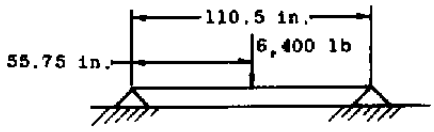


Figure 5. Test installation.



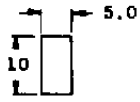
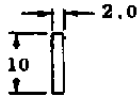
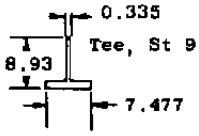
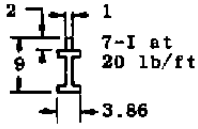
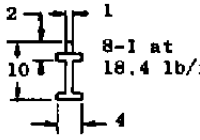
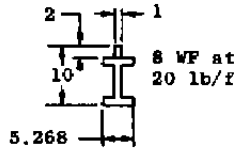
	Beams Considered	Load, lb	Weight/ft, lb	Stress, psi	Deflection, in.	Δ/L, in./ft
1		6,400	168	2,122	0.015	0.0011
2		6,400	67.2	5,303	0.037	0.0026
3		6,400	22.5	24,500	0.127	0.0090
4		6,400	26.72	11,300	0.085	0.0060
5		6,400	25.12	10,100	0.066	0.0047
6		6,400	26.72	8,700	0.058	0.0041

Figure 6. Rail cross sections.

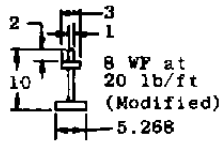
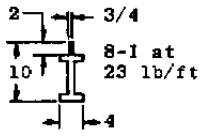
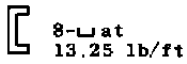
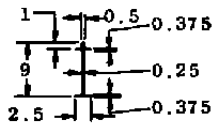
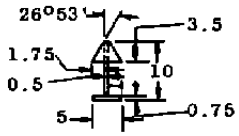
	Beams Considered	Load, lb	Weight/ft, lb	Stress, psi	Deflection, in.	Δ/L, in./ft
7		6,400	23.84	8,800	0.061	0.0043
8		6,400	25.04	9,100	0.065	0.0046
9		6,400	13.75	19,800	0.173	0.0123
10		6,400	14.07	18,200	0.140	0.0099
11		6,400	20.16	29,500	0.344	0.0244
12		6,400	48.7	5,500	0.038	0.0027

Figure 6. Concluded.

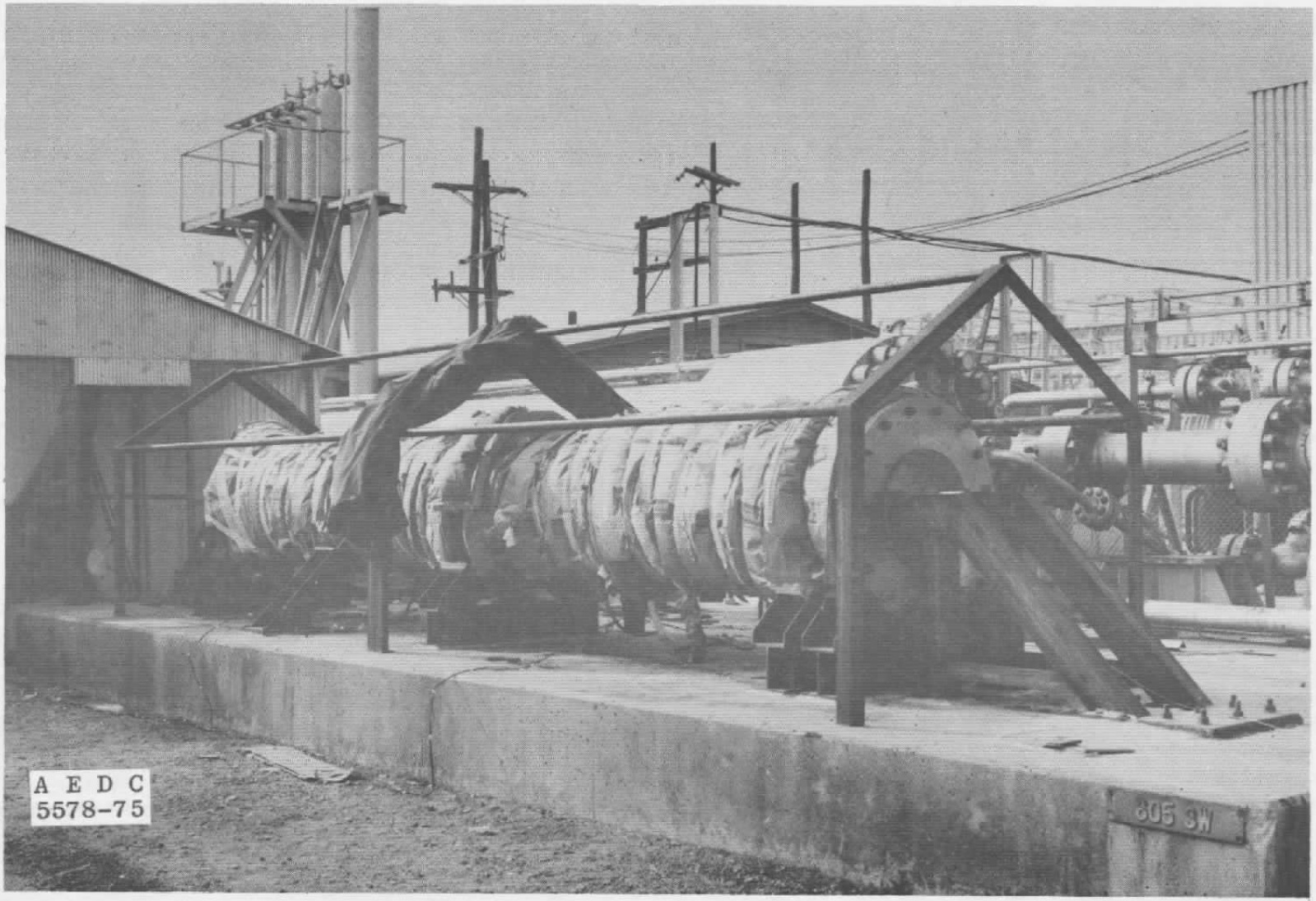


Figure 7. Insulated assembly.

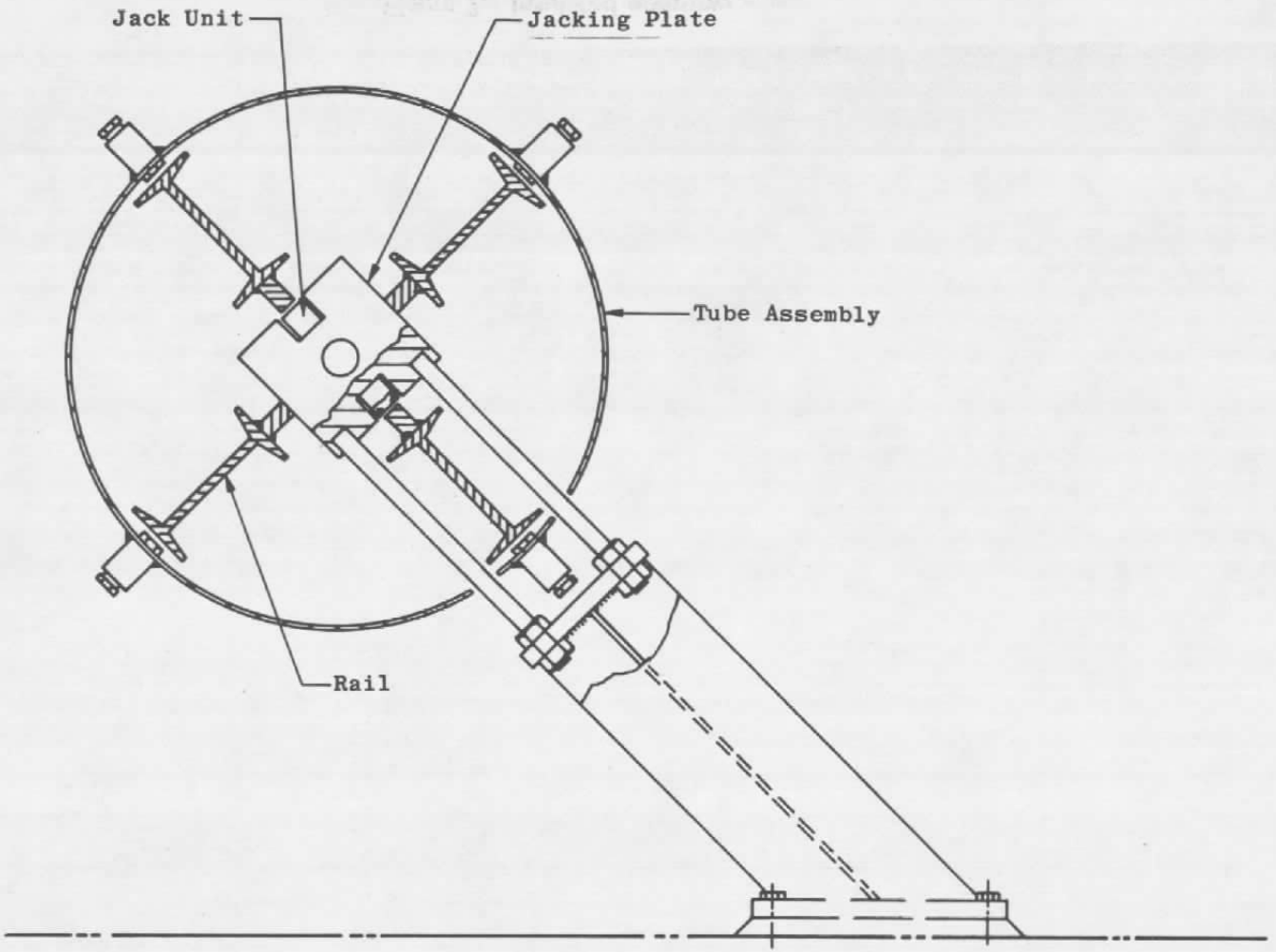


Figure 8. Rail loading device.

Figure 9. Test assembly with sunshade.

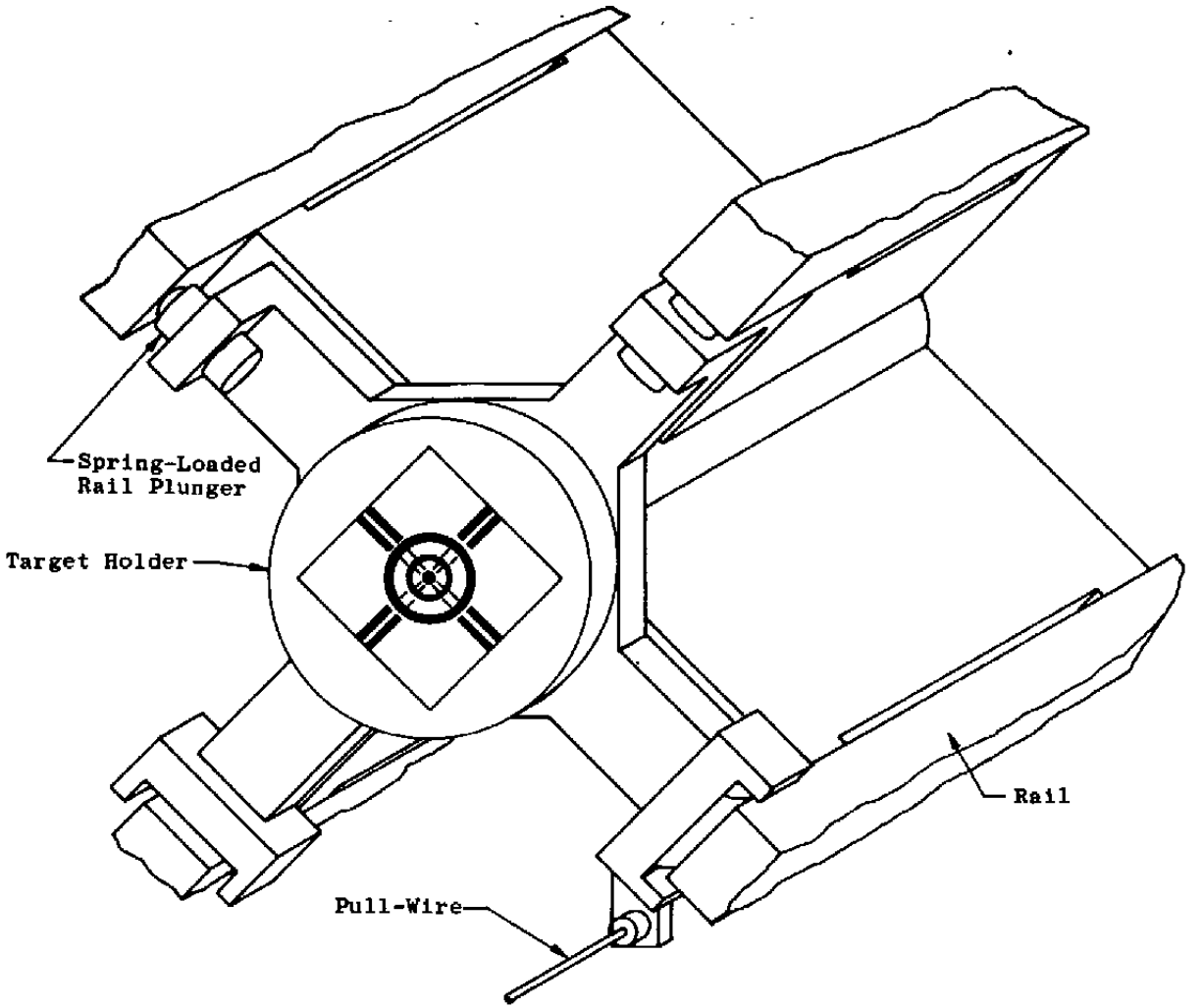


Figure 10. Target holder.

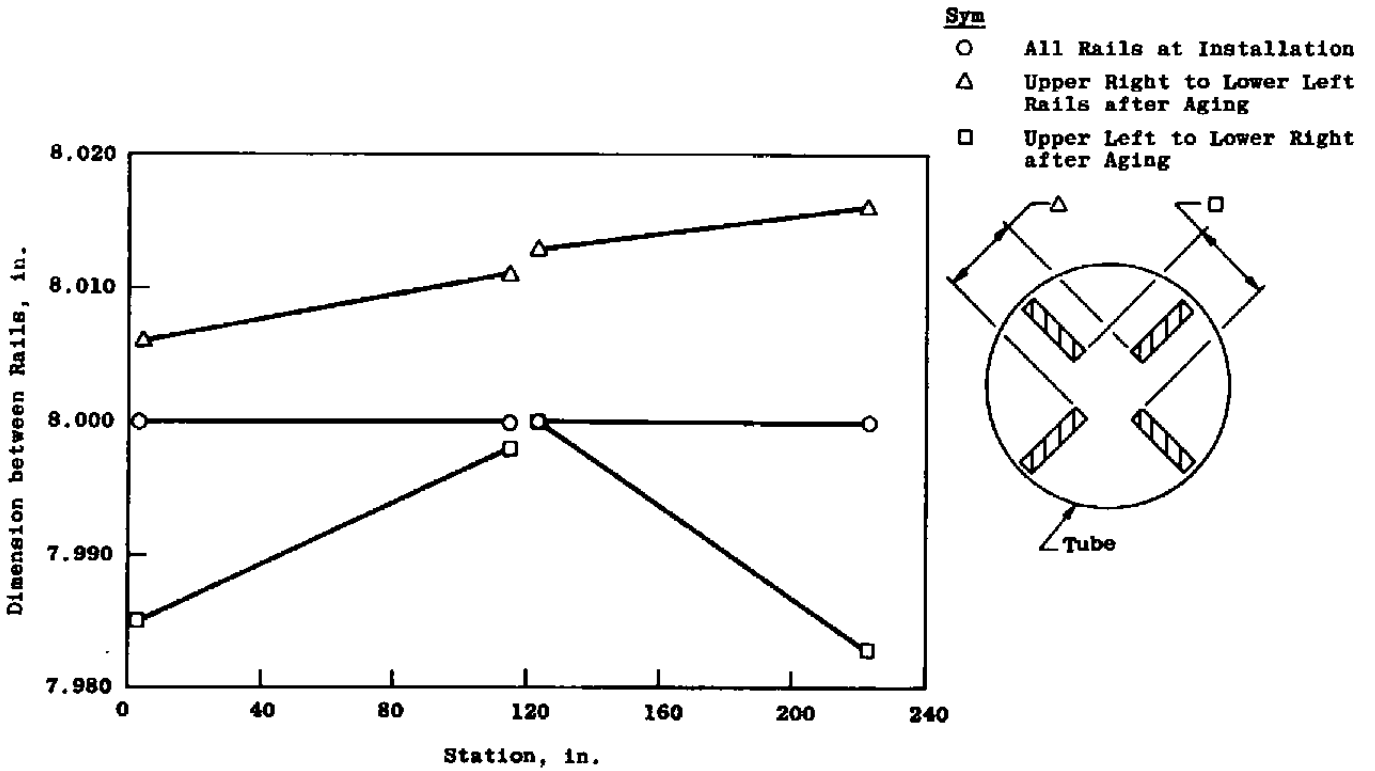


Figure 11. Change in dimensions between rails due to aging.

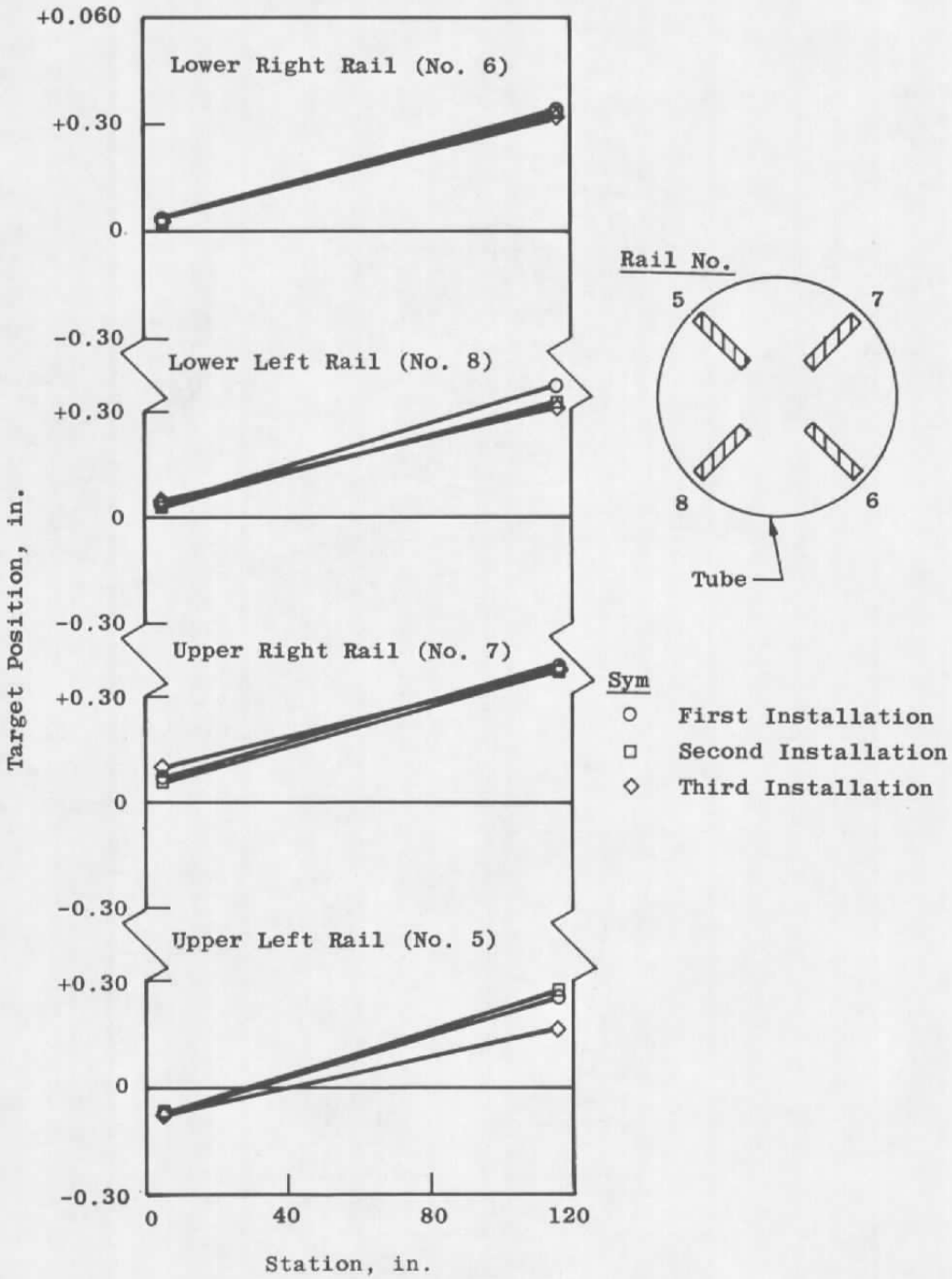


Figure 12. Installation repeatability with centerline guides.

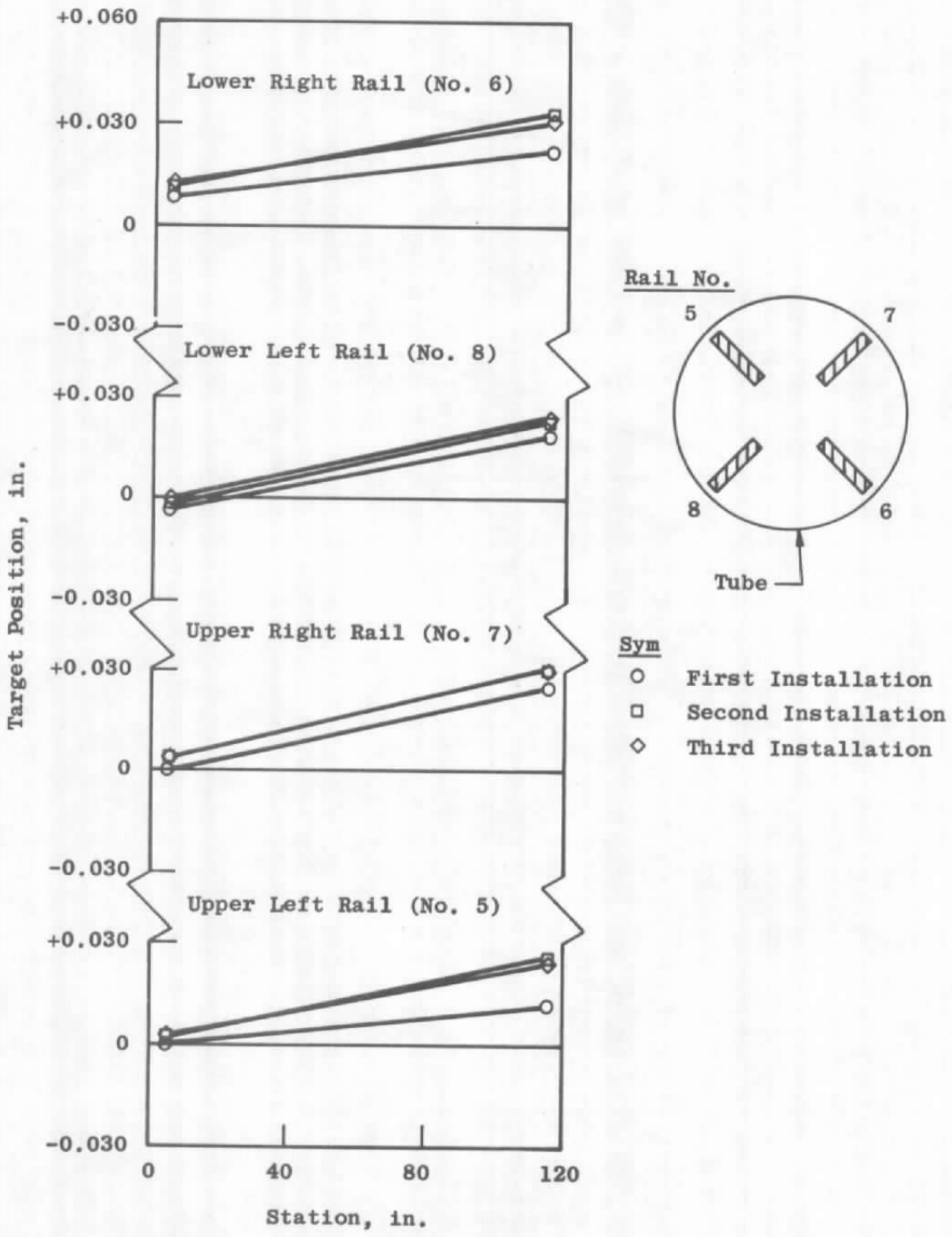


Figure 13. Installation repeatability without centerline guides.

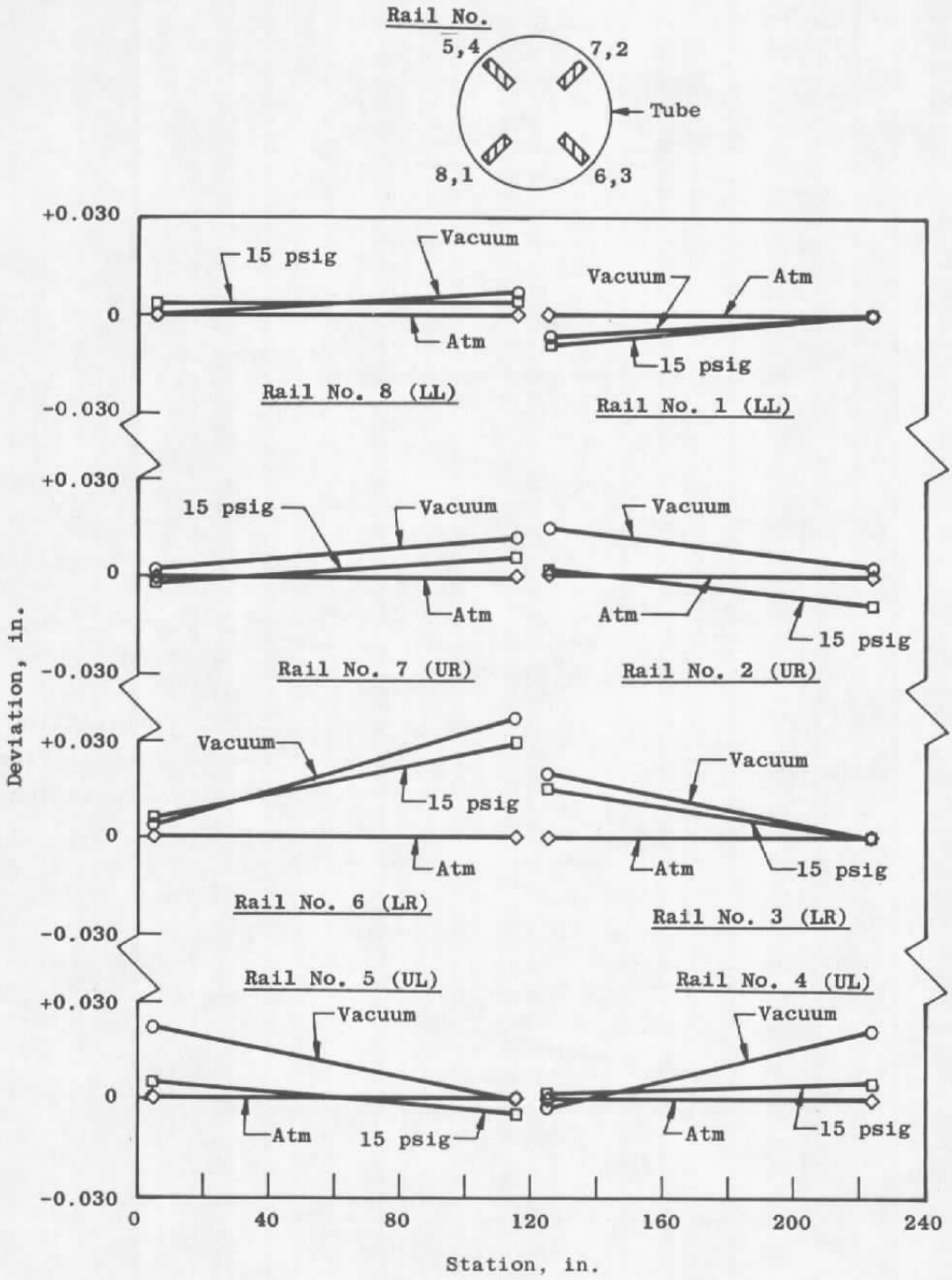


Figure 14. Modified I-rail, 25.12 lb/ft, displacements for atmospheric pressure, vacuum, and 15 psig (with sunshade).

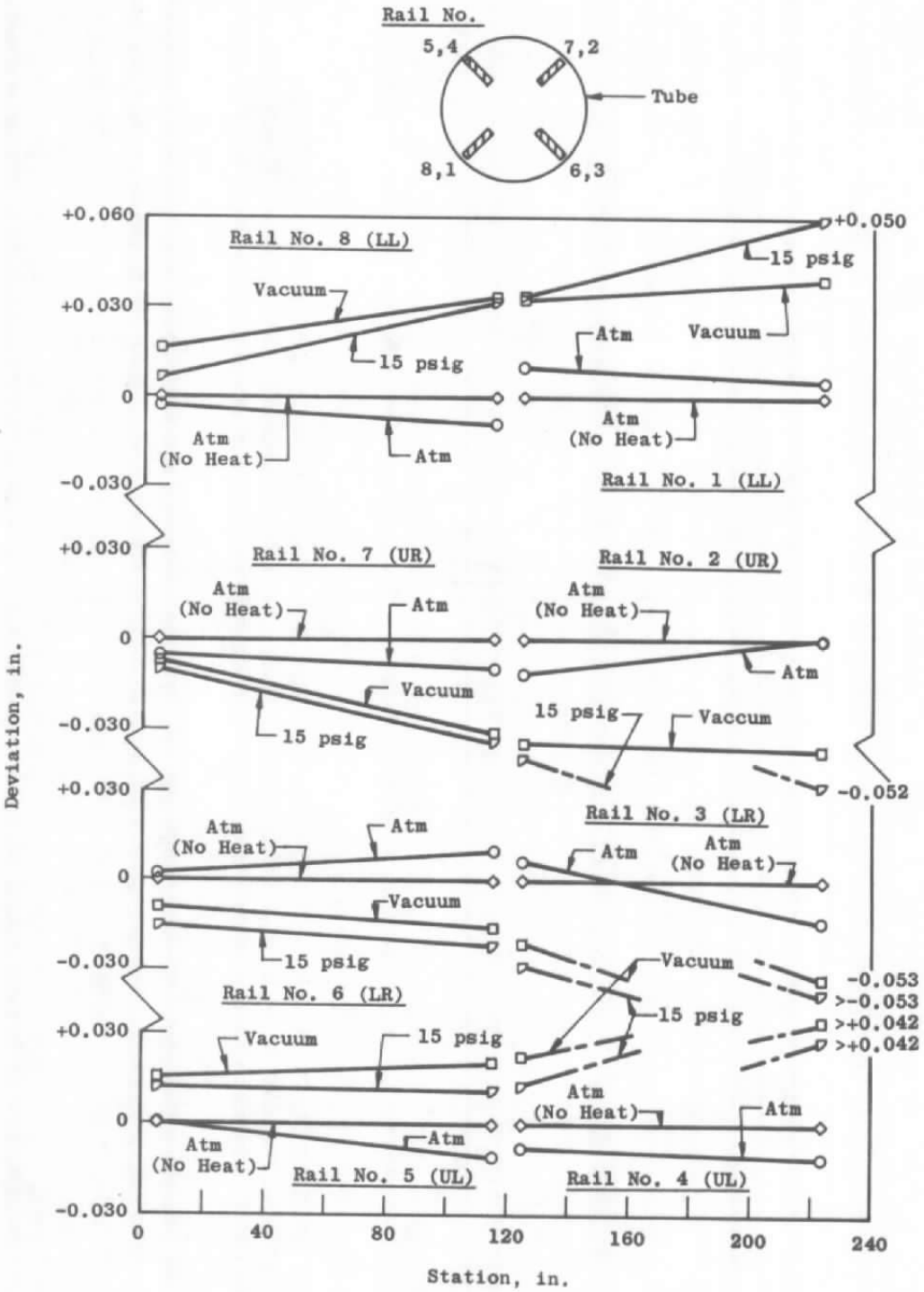


Figure 15. Modified I-rail, 25.12 lb/ft, displacements for atmospheric pressure, vacuum, and 15 psig (with top heated, $\Delta T = 30^{\circ}F$).

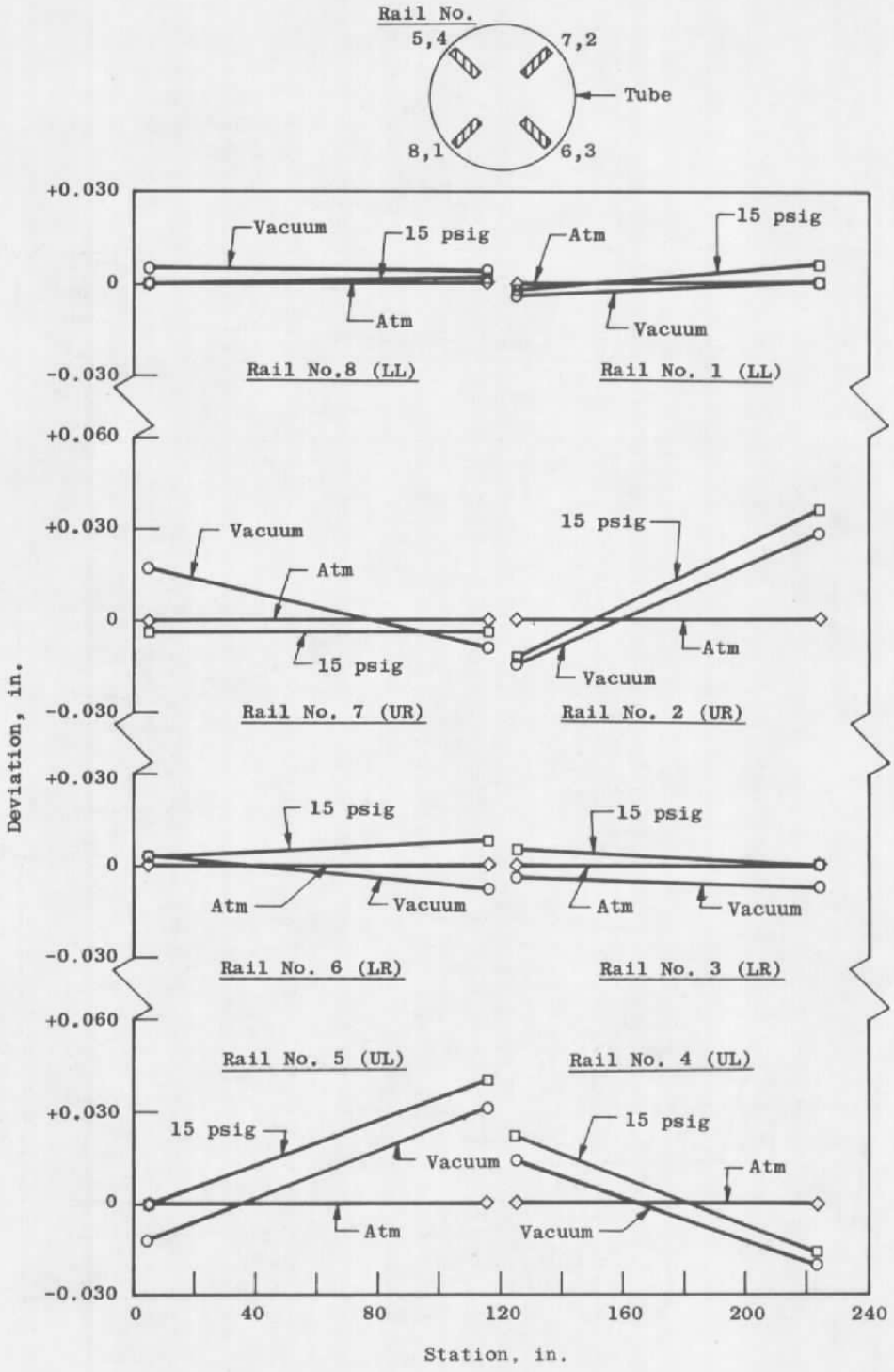


Figure 16. Modified I-rail 25.12 lb/ft, center support, displacements for atmospheric pressure, vacuum, and 15 psig (with sunshade).

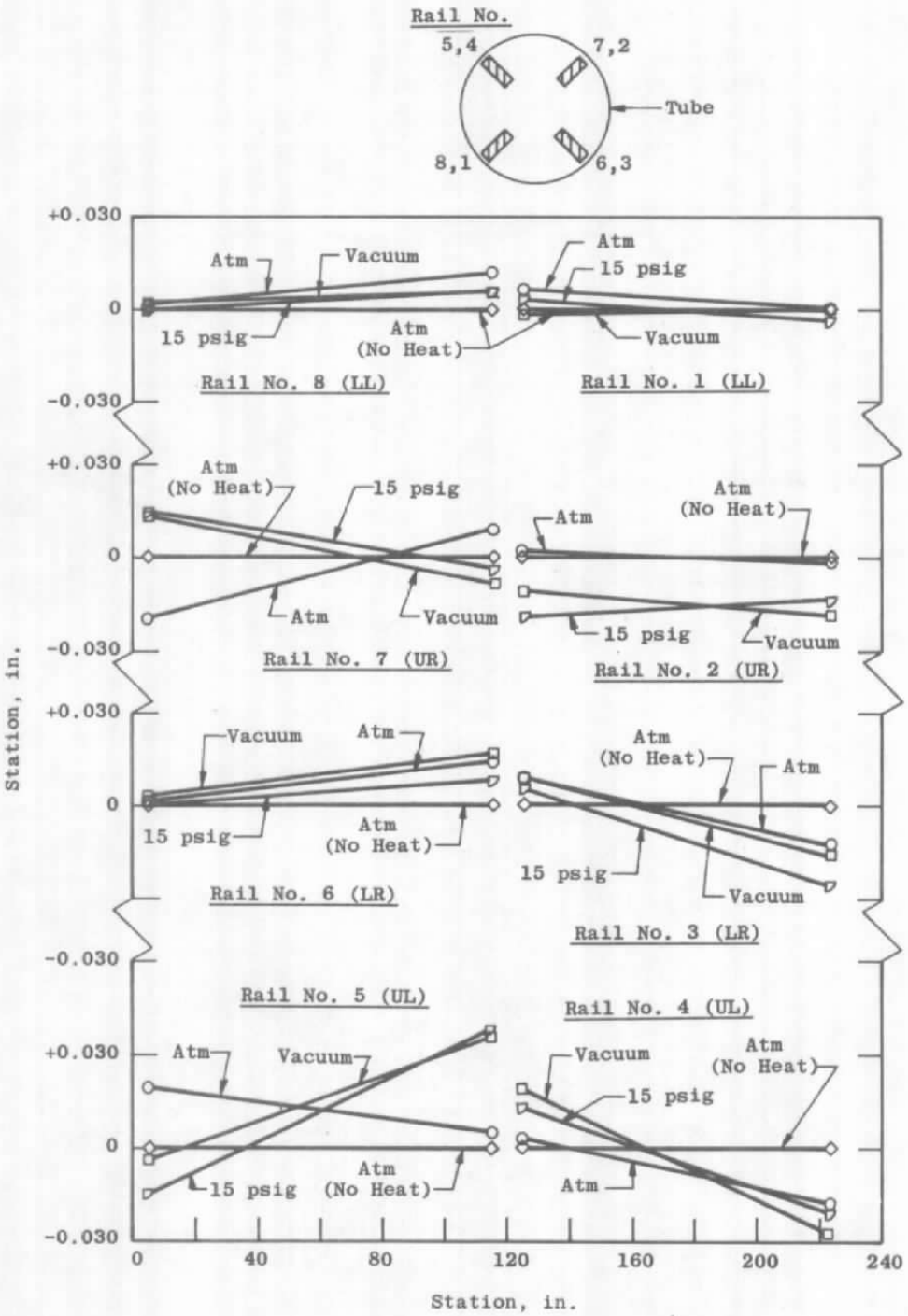


Figure 17. Modified I-rail, 25.12 lb/ft, center support, displacements for atmospheric pressure, vacuum, and 15 psig (with top heated, $\Delta T = 30^{\circ}F$).

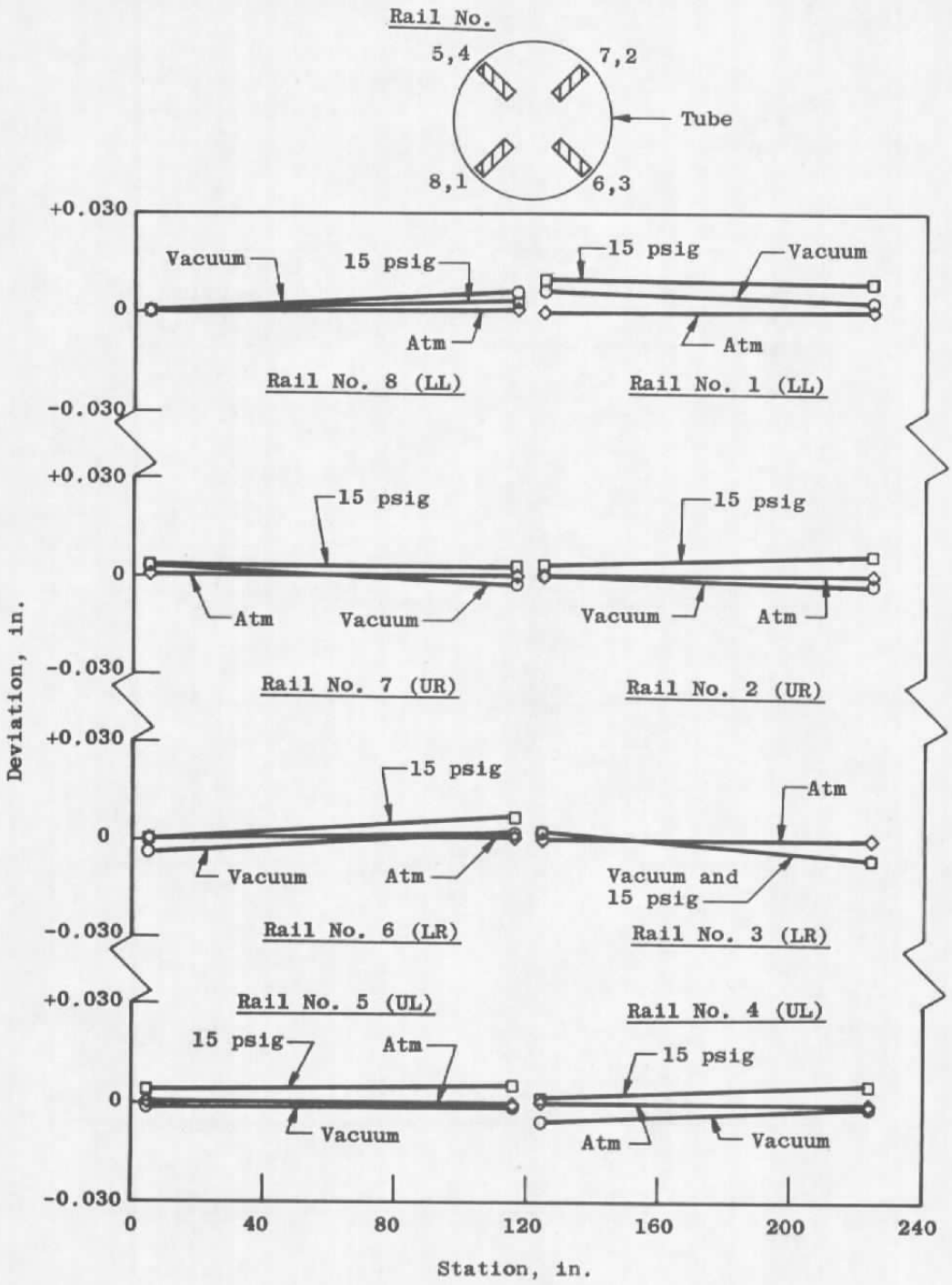


Figure 18. Modified I-rail, 25.12 lb/ft, insulated, displacements for atmospheric pressure, vacuum, and 15 psig.

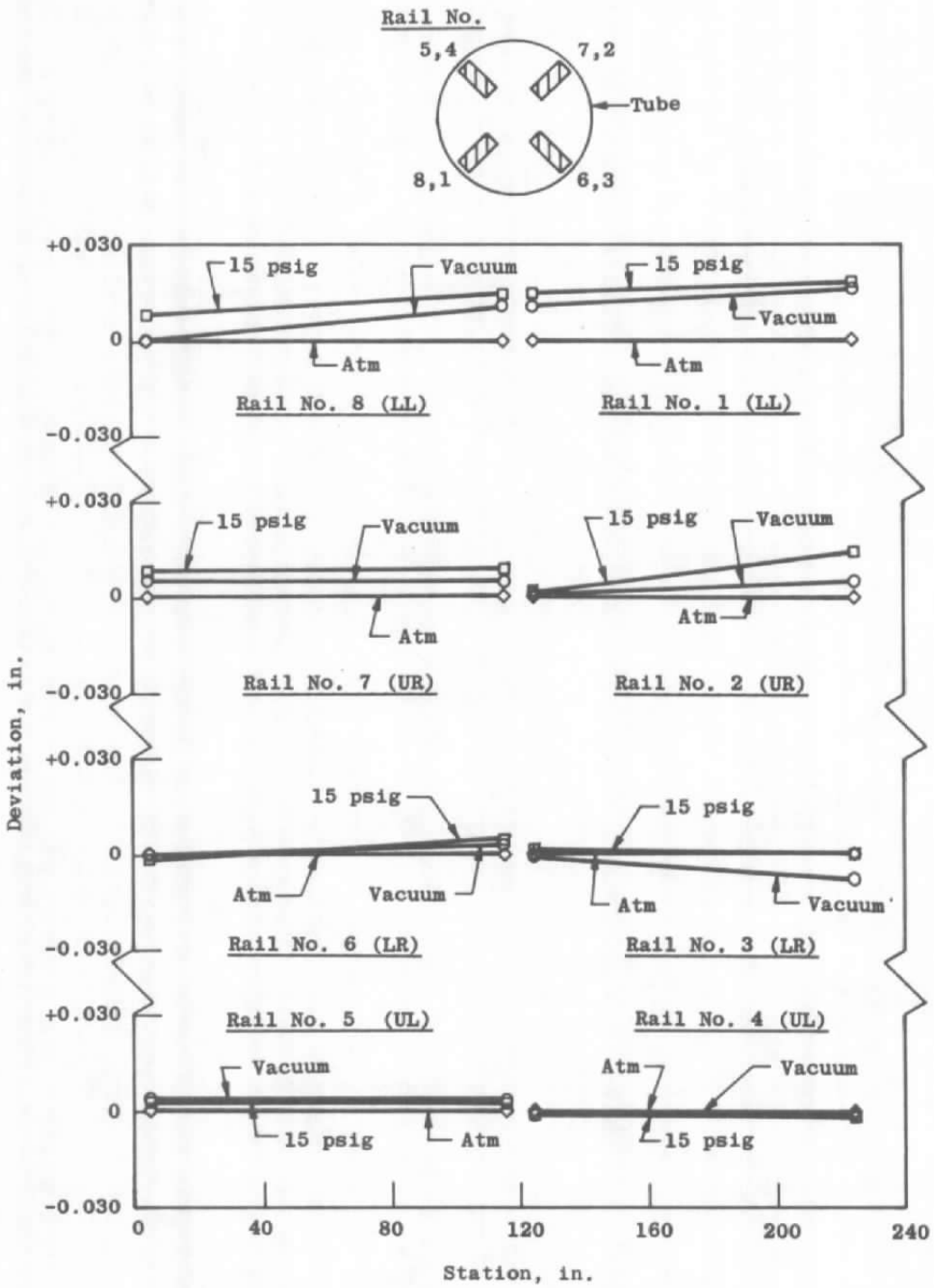


Figure 19. Modified I-rail, 25.12 lb/ft, center support, insulated, displacements for atmospheric pressure, vacuum, and 15 psig.

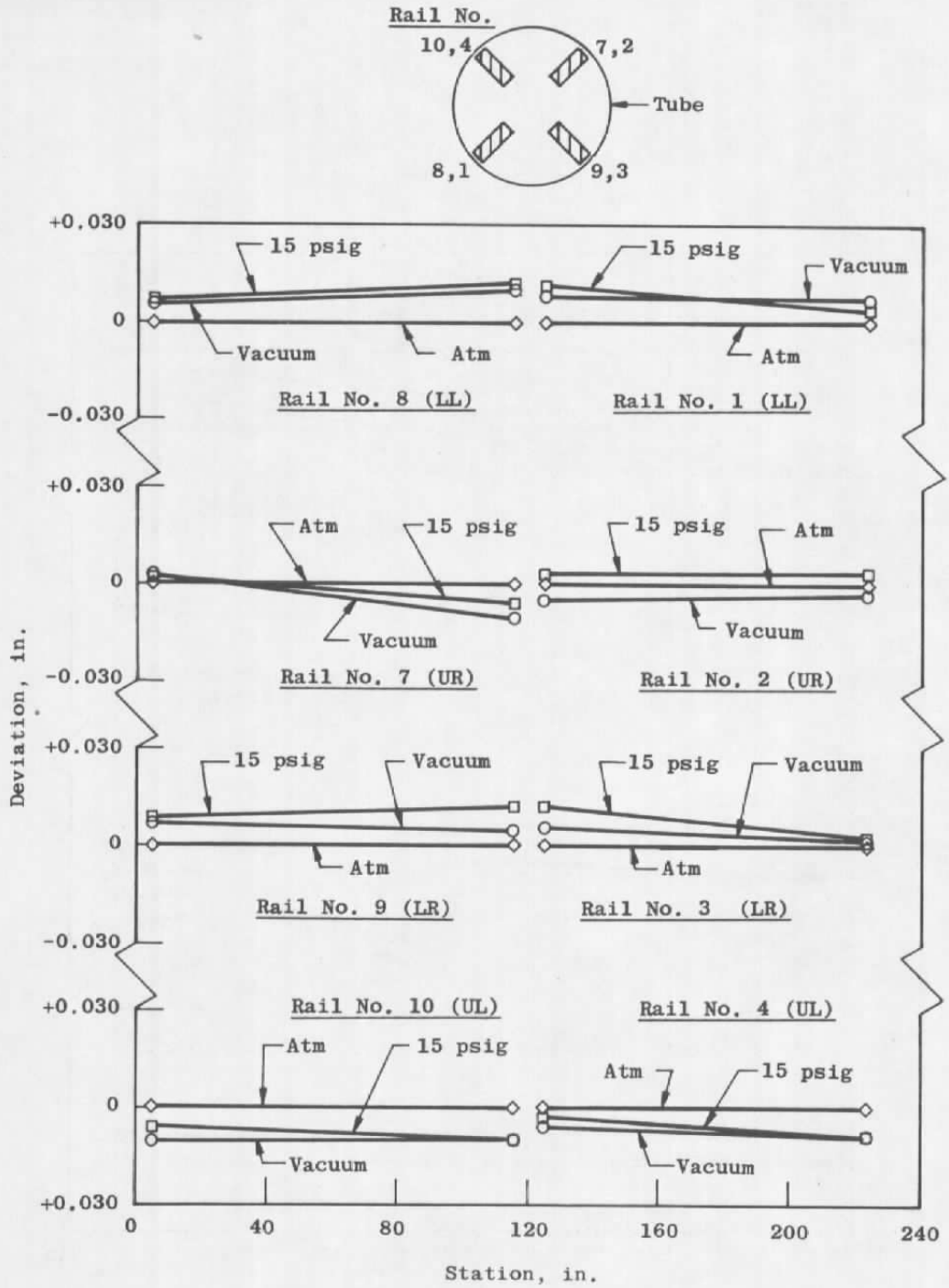


Figure 20. Special I-shape, 48.7 lb/ft for rails No. 9 and 10, all others 25.12 lb/ft, displacements for atmospheric pressure, vacuum, and 15 psig.

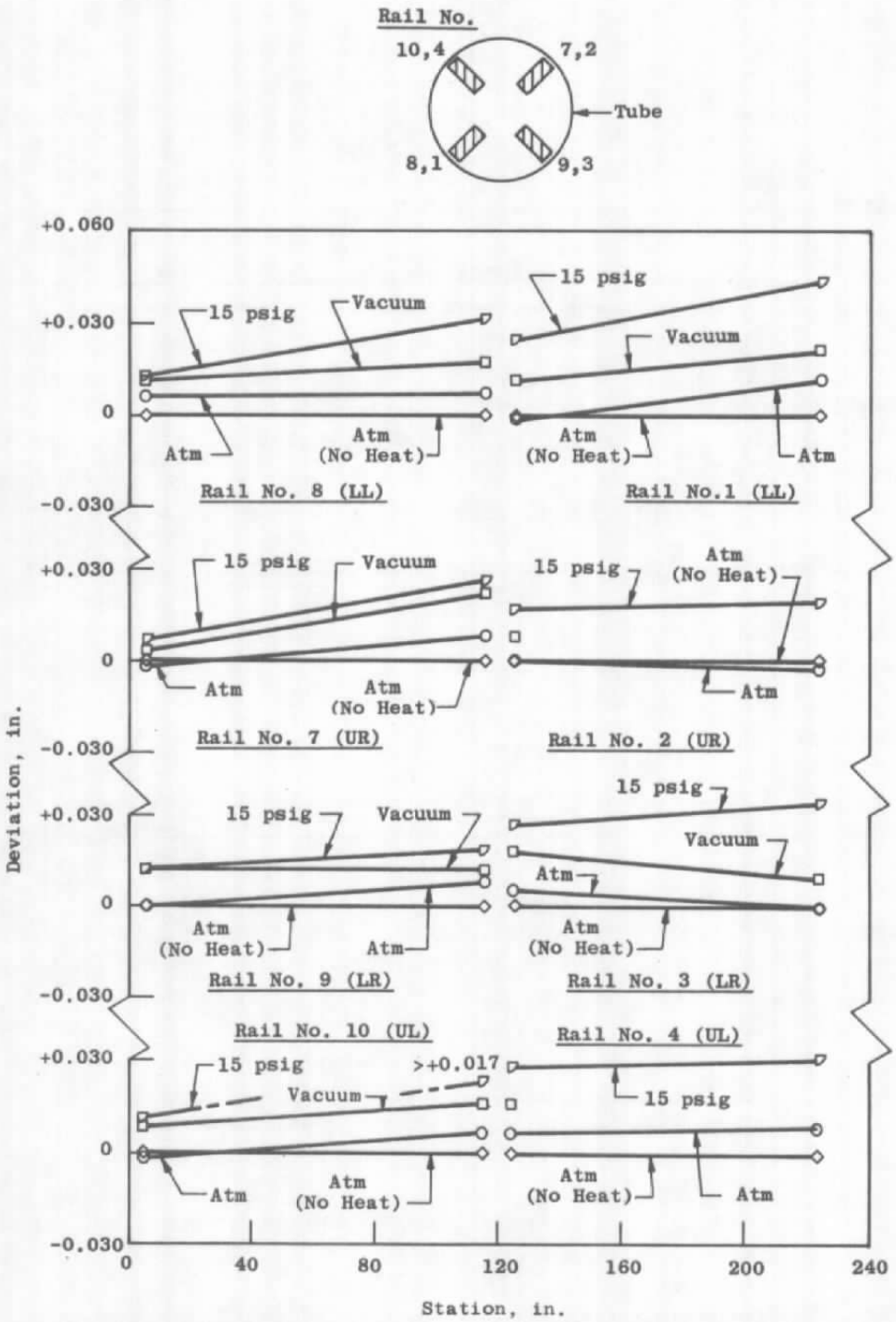


Figure 21. Special I-shape, 48.7 lb/ft for rails No. 9 and 10, all others 25.12 lb/ft, displacements for atmospheric pressure, vacuum, and 15 psig (with top heated, $\Delta T = 30^{\circ}F$).

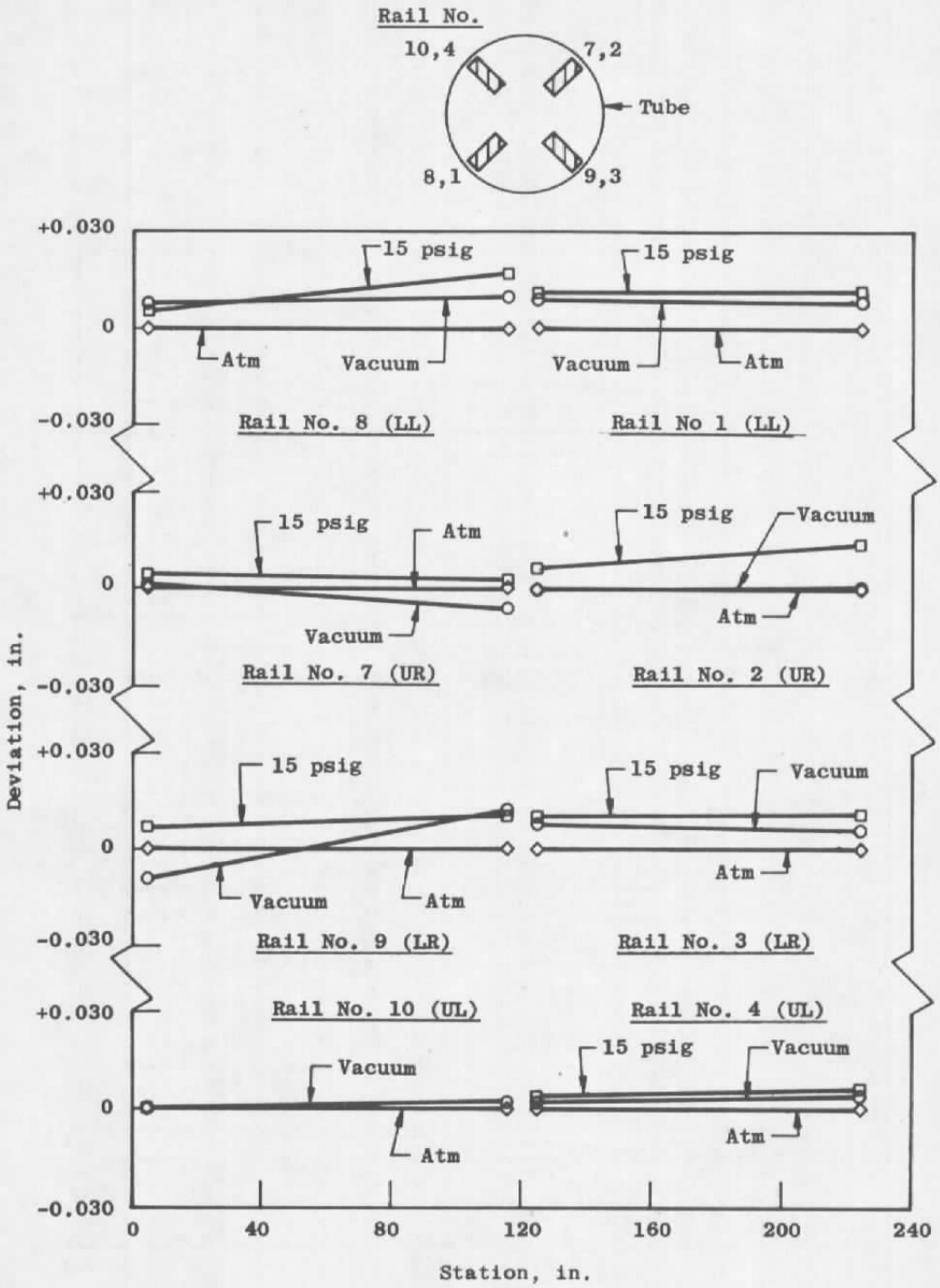


Figure 22. Special I-shape, 48.7 lb/ft for rails No. 9 and 10, all others 25.12 lb/ft, center support, displacements for atmospheric pressure, vacuum, and 15 psig.

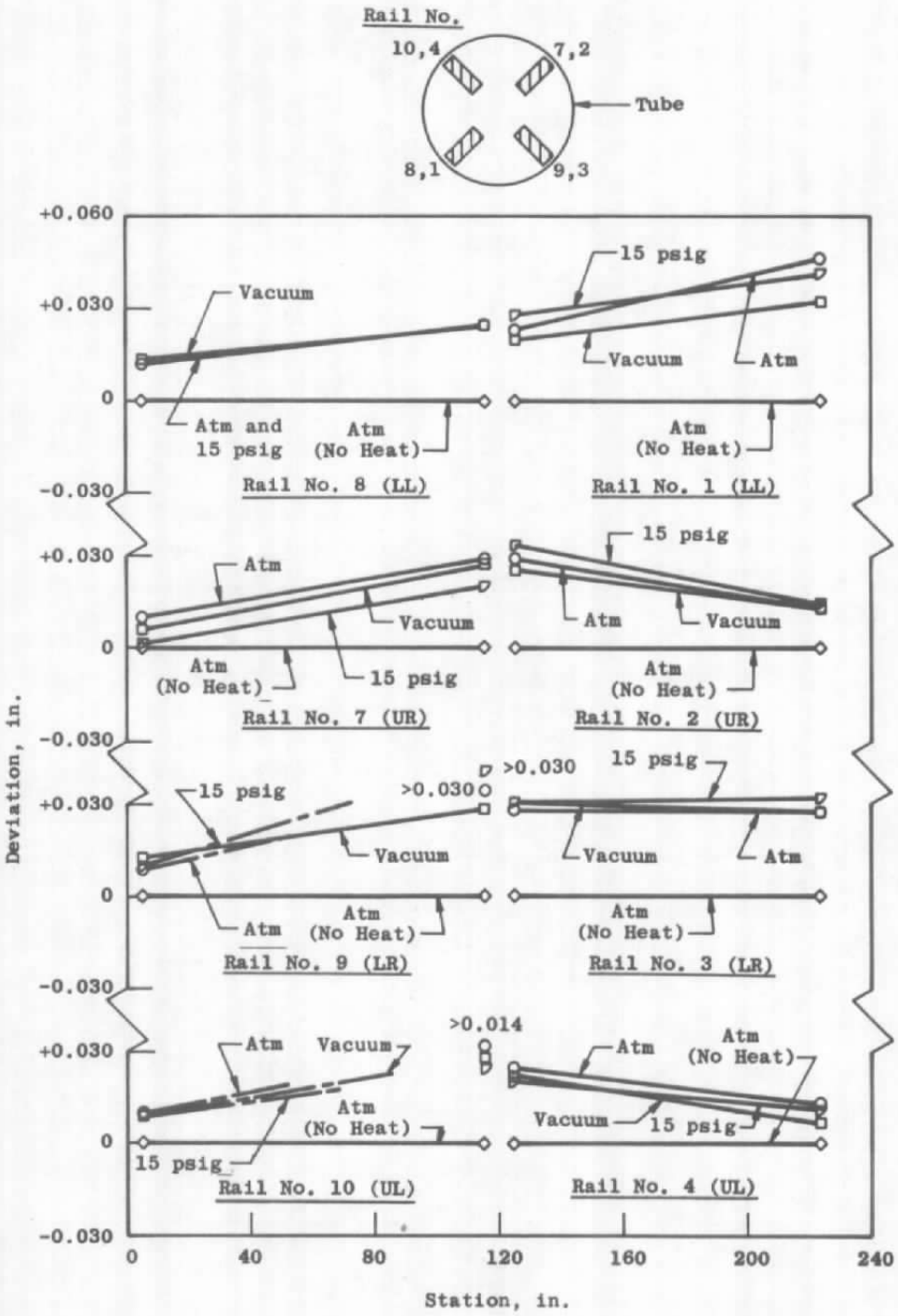
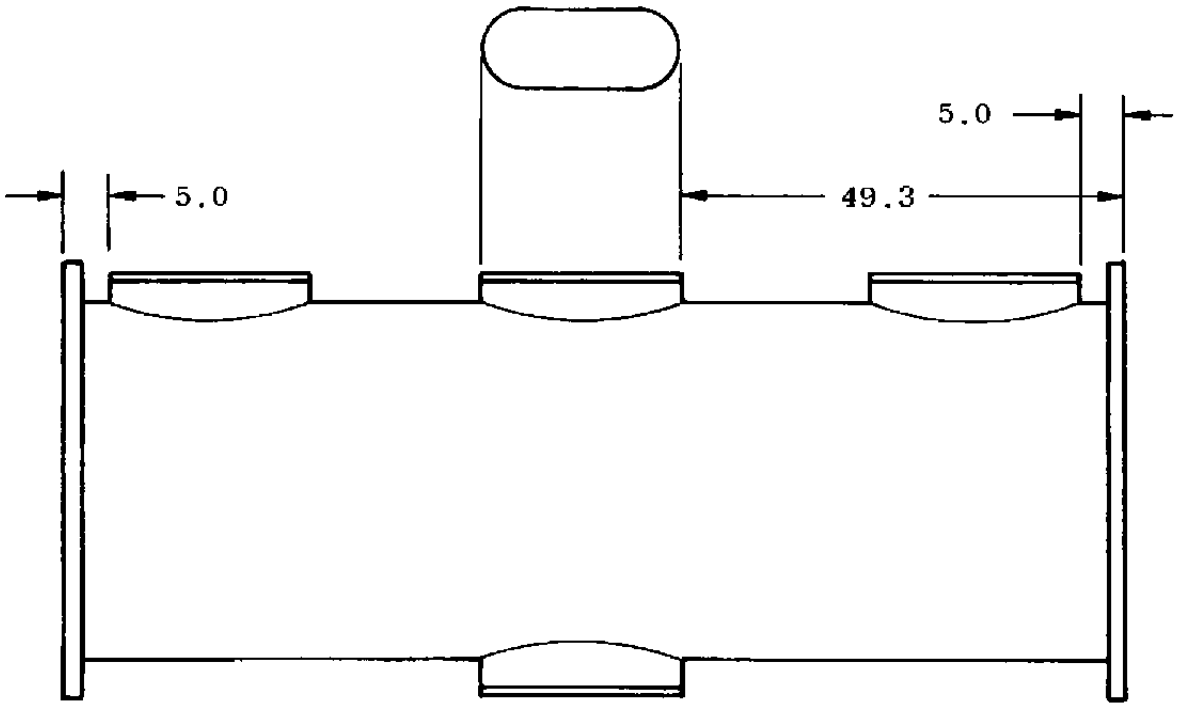


Figure 23. Special I-shape, 48.7 lb/ft for rails No. 9 and 10, all others 25.12 lb/ft, center support, displacements for atmospheric pressure, vacuum, and 15 psig (with top heated, $\Delta T = 30^{\circ}F$).



All Dimensions in Inches

Figure 24. Penetration in shell.

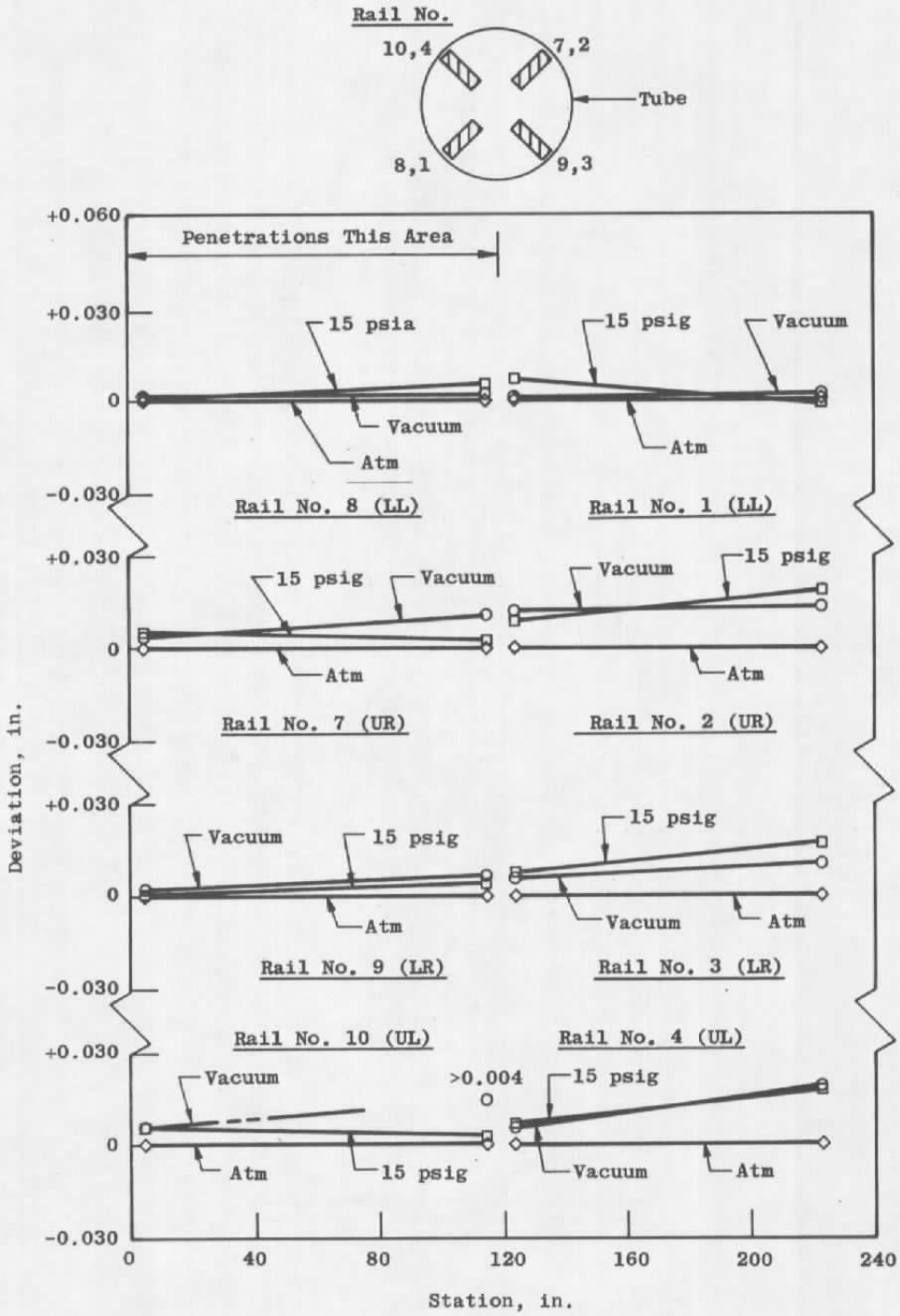


Figure 25. Rail displacements caused by tube penetrations, for atmospheric pressure, vacuum, and 15 psig.

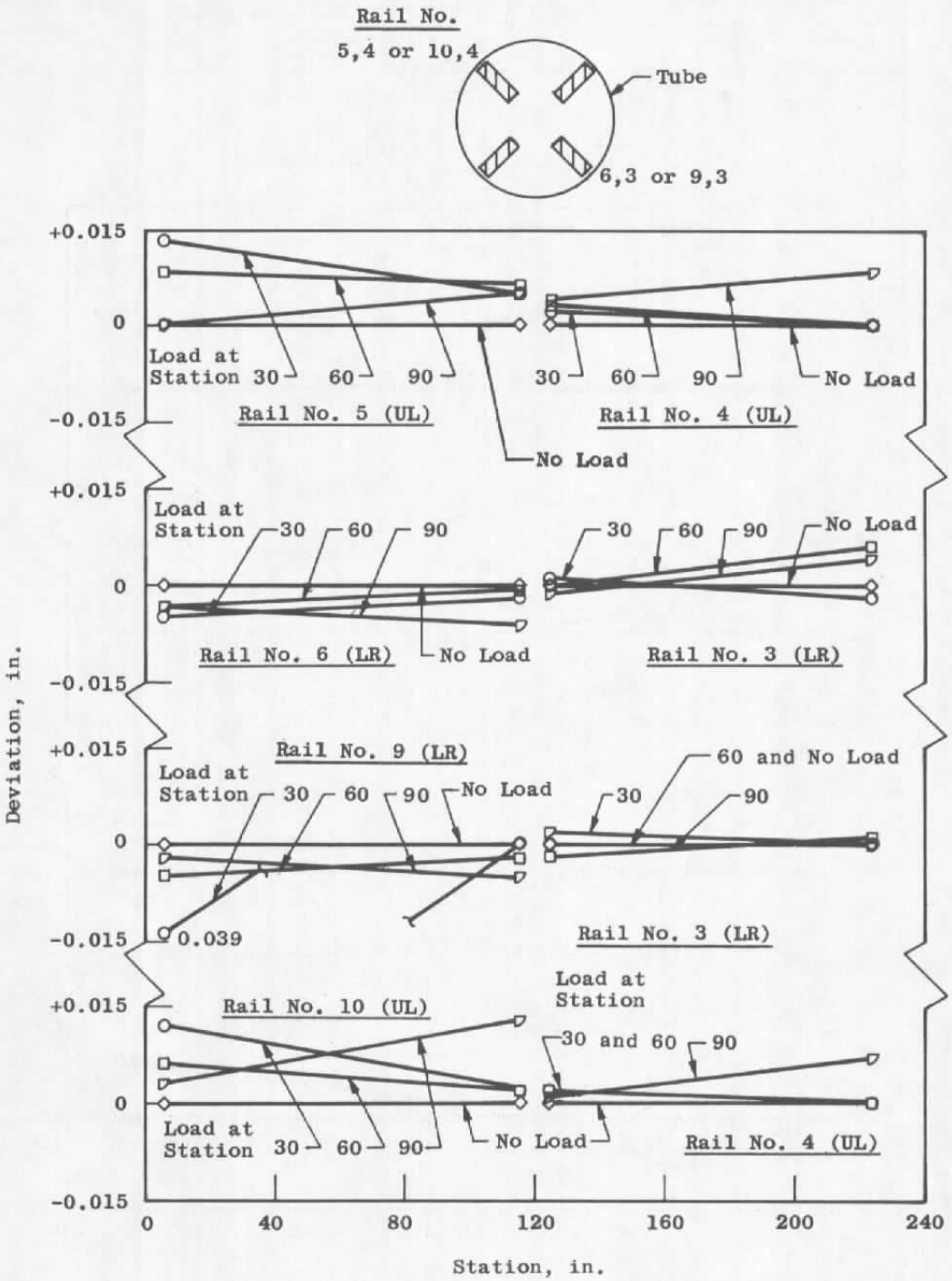


Figure 26. Rail displacements caused by loading (rails 9 and 10, 48.7 lb/ft; all others, 25.12 lb/ft).

Table 1. Summary of Test Conditions and Results

Test Configuration	Rail Position, in.	Pressure			Test Conditions						
		Atmospheric	15 psig	Vacuum	Sunshield	Insulated	Without Heat	With Heat	Without Center Support	With Center Support	Loaded at Stations 30, 60, and 90
Section 5.3 Figure 14	Maximum Displacement		0.029	0.037	X		X		X		
	Maximum Step (Actual Measurement)	0.010	0.012	0.013	X		X		X		
	Maximum Step (With Perfect Initial Alignment)		0.014	0.017	X		X		X		
Section 5.3 Figure 15	Maximum Displacement	0.014	>0.053	0.053	X			X	X		
	Maximum Step (Actual Measurement)	0.016	0.018	0.017	X			X	X		
	Maximum Step (With Perfect Initial Alignment)	0.019	0.006	0.005	X			X	X		
Section 5.4 Figure 16	Maximum Displacement		0.040	0.031	X		X			X	
	Maximum Step (Actual Measurement)	0.010	0.013	0.014	X		X			X	
	Maximum Step (With Perfect Initial Alignment)		0.018	0.017	X		X			X	
Section 5.4 Figure 17	Maximum Displacement	0.020	0.038	0.035	X			X		X	
	Maximum Step (Actual Measurement)	0.015	0.015	0.018	X			X		X	
	Maximum Step (With Perfect Initial Alignment)	0.007	0.025	0.016	X			X		X	

Table 1. Continued

Test Configuration	Rail Position in.	Pressure			Test Conditions						
		Atmospheric	15 psig	Vacuum	Sunshield	Insulated	Without Heat	With Heat	Without Center Support	With Center Support	Loaded at Stations 30, 60, and 90
Section 5.5 Figure 18	Maximum Displacement		0.010	0.006		X	X		X		
	Maximum Step (Actual Measurement)	0.008	0.013	0.010		X	X		X		
	Maximum Step (With Perfect Initial Alignment)		0.006	0.004		X	X		X		
Section 5.6 Figure 19	Maximum Displacement		0.018	0.016		X	X			X	
	Maximum Step (Actual Measurement)	0.008	0.012	0.012		X	X			X	
	Maximum Step (With Perfect Initial Alignment)		0.007	0.005		X	X			X	
Section 5.7 Figure 20	Maximum Displacement		0.012	0.011	X		X		X		
	Maximum Step (Actual Measurement)	0.012	0.008	0.011	X		X		X		
	Maximum Step (With Perfect Initial Alignment)		0.009	0.005	X		X		X		

Table 1. Continued

Test Configuration	Rail Position, in.	Pressure			Test Conditions						
		Atmospheric	15 psig	Vacuum	Sunshield	Insulated	Without Heat	With Heat	Without Center Support	With Center Support	Loaded at Stations 30, 60, and 90
Section 5.7 Figure 21	Maximum Displacement	0.011	0.044	0.022	X			X	X		
	Maximum Step (Actual Measurement)	0.014	0.003	0.012	X			X	X		
	Maximum Step (With Perfect Initial Alignment)	0.008	>0.011	0.014	X			X	X		
Section 5.8 Figure 22	Maximum Displacement		0.017	0.012	X		X			X	
	Maximum Step (Actual Measurement)	0.016	>0.014	0.016	X		X			X	
	Maximum Step (With Perfect Initial Alignment)		0.006	0.006	X		X			X	
Section 5.8 Figure 23	Maximum Displacement	0.046	0.041	0.032	X			X		X	
	Maximum Step (Actual Measurement)	>0.007	0.008	0.007	X			X		X	
	Maximum Step (With Perfect Initial Alignment)	>0.010	0.013	>0.008	X			X		X	

Table 1. Concluded

Test Configuration	Rail Position, in.	Pressure			Test Conditions						
		Atmospheric	15 psig	Vacuum	Sunshield	Insulated	Without Heat	With Heat	Without Center Support	With Center Support	Loaded at Stations 30, 60, and 90
Section 5.9 Figure 25	Maximum Displacement		0.019	0.019	X		X		X		
	Maximum Step (Actual Measurement)	0.013	0.009	>0.012	X		X		X		
	Maximum Step (With Perfect Initial Alignment)		0.006	0.001	X		X		X		
Section 5.10.1 Figure 26	Maximum Displacement	0.013			X		X		X		X
	Maximum Step (Actual Measurement)	0.019			X		X		X		X
	Maximum Step (With Perfect Initial Alignment)	0.012			X		X		X		X
Section 5.10.2 Figure 26	Maximum Displacement	0.039			X		X		X		X
	Maximum Step (Actual Measurement)	0.023			X		X		X		X
	Maximum Step (With Perfect Initial Alignment)	0.012			X		X		X		X

APPENDIX A
TABULATED DATA

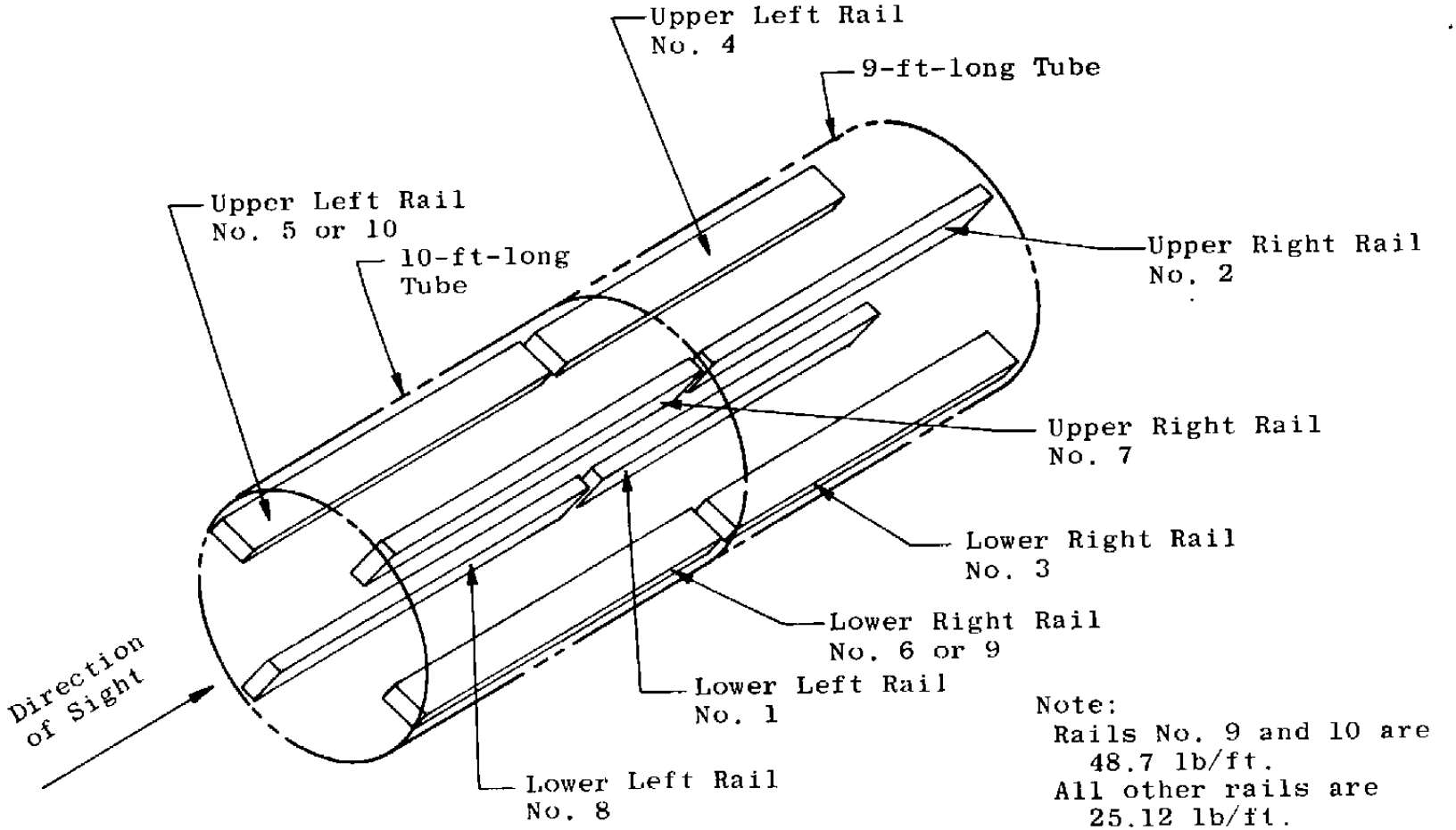


Figure A-1. Rail numbering and location scheme.

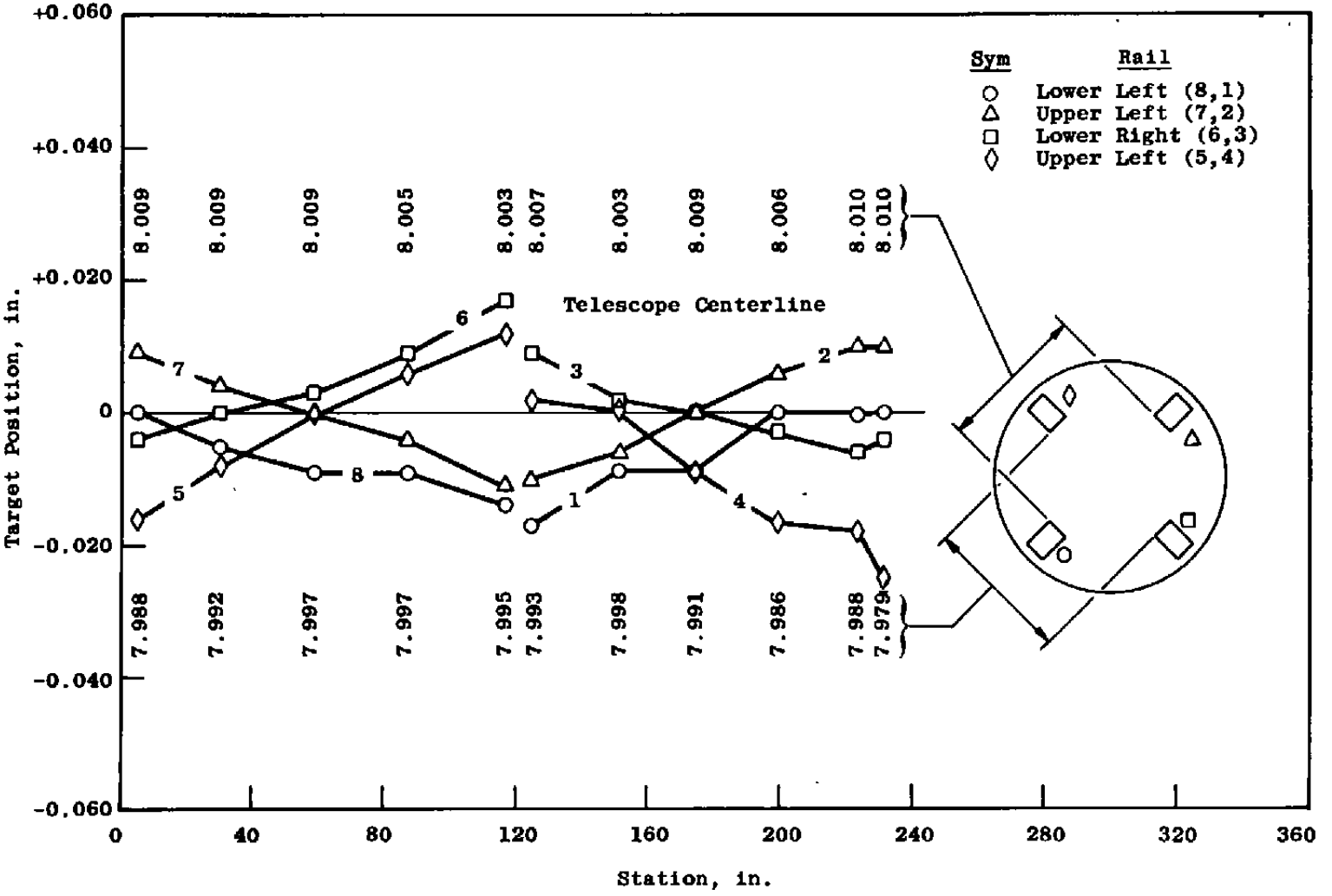


Figure A-2. Modified I-beam, 25.12 lb/ft, vacuum, insulated.

Table A-1. Straightness of Rails (25.12 lb/ft and 48.7 lb/ft)

Rail No.		Distance from End of Rail, ft										
		0	1	2	3	4	5	6	7	8	9	10
1	BT*	0.000	0.000	-0.001	-0.001	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	0.000
	AT*	0.000	0.000	+0.001	0.000	+0.001	+0.001	+0.001	+0.001	+0.001	+0.001	0.000
2	BT	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	0.000	0.000	0.000
	AT	0.000	0.000	0.000	+0.001	+0.001	+0.001	+0.001	+0.001	0.000	-0.001	0.000
3	BT	0.000	+0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	AT	0.000	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	0.000
4	BT	0.000	-0.001	-0.001	-0.001	-0.002	-0.002	-0.001	-0.001	-0.001	0.000	0.000
	AT	0.000	0.000	-0.001	-0.001	-0.002	-0.002	-0.002	-0.001	0.000	0.000	0.000
5	BT	0.000	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	0.00
	AT	0.000	-0.001	-0.001	-0.001	-0.001	0.000	0.000	+0.001	+0.001	0.000	0.000
6	BT	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	0.000	0.000
	AT	0.000	+0.001	+0.001	+0.002	+0.002	+0.003	+0.003	+0.003	+0.002	0.000	0.000
7	BT	0.000	0.000	-0.001	-0.002	-0.002	-0.002	-0.003	-0.002	-0.002	-0.001	0.000
	AT	0.000	+0.002	+0.003	+0.003	+0.003	+0.003	+0.003	+0.002	+0.002	+0.001	0.000
8	BT	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.000	0.000
	AT	0.000	0.000	-0.001	-0.001	-0.001	-0.001	0.000	-0.001	0.000	-0.002	0.000
9 **	BT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	AT	0.000	+0.002	+0.005	+0.007	+0.008	+0.009	+0.008	+0.008	+0.005	+0.002	0.000
10 **	BT	0.000	+0.001	+0.002	+0.003	+0.004	+0.006	+0.008	+0.006	+0.005	+0.002	0.000
	AT	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	0.000	0.000	0.000	0.000

*BT - Before Testing, AT - After Testing

**48.7 lb/ft

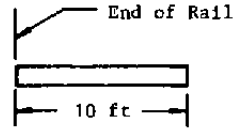


Table A-2. End Misalignments and Dimensions between Rails

Item No.	Rail Configuration	Test Condition	Rails		Measured End Misalignment Maximum, in.	Rail Spacing Over Full Length 8.000±, in.	Remarks
			Location	No.			
1	25.12 lb/ft	Atmospheric Pressure with Sunshade	LL	8 & 1	0.010	+0.014	
			UR	7 & 2	0	−0.016	
			LR	6 & 3	0.004	+0.004	
			UL	5 & 4	0.006	−0.012	
2		Vacuum with Sunshade	LL	8 & 1	0.004	+0.026	
			UR	7 & 2	0.003	−0.015	
			LR	6 & 3	0.013	+0.021	
			UL	5 & 4	0.009	−0.046	
3		15 psig with Sunshade	LL	8 & 1	0.003	+0.016	
			UR	7 & 2	0.004	−0.026	
			LR	6 & 3	0.010	+0.005	
			UL	5 & 4	0.012	−0.042	
4		Atmospheric Pressure Top Heated 30 deg Approximate	LL	8 & 1	0.001	+0.017	
			UR	7 & 2	0.001	−0.006	
			LR	6 & 3	0.016	+0.031	
			UL	5 & 4	0.009	−0.048	
5		Vacuum Top Heated 30 deg Approximate	LL	8 & 1	0.001	−0.023	
			UR	7 & 2	0.001	−0.073	
			LR	6 & 3	0.017	+0.009	
			UL	5 & 4	0.008	>+0.106	
6		15 psig Top Heated 30 deg Approximate	LL	8 & 1	0.002	−0.021	
			UR	7 & 2	0.001	−0.094	
			LR	6 & 3	0.018	>+0.108	
			UL	5 & 4	0.008	+0.006	
7		Atmospheric Pressure with Sunshade Rail Support at Center	LL	8 & 1	0.002	+0.017	
			UR	7 & 2	0.004	−0.019	
			LR	6 & 3	0.010	+0.004	
			UL	5 & 4	0.010	−0.032	
8		Vacuum with Sunshade Rail Support at Center	LL	8 & 1	0.008	+0.018	
			UR	7 & 2	0.002	+0.002	
			LR	6 & 3	0.014	−0.001	
			UL	5 & 4	0.007	−0.017	
9		15 psig with Sunshade Rail Support at Center	LL	8 & 1	0.001	+0.011	
			UR	7 & 2	0.004	−0.010	
			LR	6 & 3	0.013	+0.008	
			UL	5 & 4	0.008	−0.034	

Table A-2 Continued

Item No.	Rail Configuration	Test Condition	Rails		Measured End Misalignment Maximum, in.	Rail Spacing Over Full Length 8.000±, in.	Remarks
			Location	No.			
10	25.12 lb/ft	Atmospheric Pressure Top Heated 30 deg Approximate Rail Support at Center	LL	8 & 1	0.007	-0.016	
			UR	7 & 2	0.005	-0.013	
			LR	6 & 3	0.015	+0.006	
			UL	5 & 4	0.011	-0.014	
11		Vacuum Top Heated 30 deg Approximate Rail Support at Center	LL	8 & 1	0.005	+0.008	
			UR	7 & 2	0.001	+0.000	
			LR	6 & 3	0.018	-0.002	
			UL	5 & 4	0.006	-0.016	
12		15 psig Top Heated 30 deg Approximate Rail Support at Center	LL	8 & 1	0	+0.011	
			UR	7 & 2	0.011	-0.005	
			LR	8 & 3	0.013	+0.011	
			UL	5 & 4	0.015	-0.012	
13		Atmospheric Pressure Insulated	LL	8 & 1	0.003	+0.016	
			UR	7 & 2	0.001	+0.006	
			LR	6 & 3	0.006	+0.000	
			UL	5 & 4	0.006	-0.017	
14		Vacuum Insulated	LL	8 & 1	0.003	+0.010	
			UR	7 & 2	0.001	+0.003	
			LR	6 & 3	0.008	-0.002	
			UL	5 & 4	0.010	-0.024	
15		15 psig Insulated	LL	8 & 1	0.003	+0.015	
			UR	7 & 2	0.001	+0.006	
			LR	6 & 3	0.013	+0.000	
			UL	5 & 4	0.009	-0.014	
16		Atmospheric Pressure Insulated Rail Support at Center	LL	8 & 1	0.003	+0.016	
			UR	7 & 2	0.001	+0.006	
			LR	6 & 3	0.008	+0.000	
			UL	5 & 4	0.006	-0.017	
17		Vacuum Insulated Rail Support at Center	LL	8 & 1	0.003	+0.012	
			UR	7 & 2	0.005	+0.000	
			LR	6 & 3	0.012	+0.000	
			UL	5 & 4	0.011	-0.011	
18		15 psig Insulated Rail Support at Center	LL	8 & 1	0.003	+0.013	
			UR	7 & 2	0.008	+0.000	
			LR	6 & 3	0.012	+0.000	
			UL	5 & 4	0.011	-0.021	

Table A-2. Continued

Item No.	Rail Configuration	Test Condition	Rails		Measured End Misalignment Maximum, in.	Rail Spacing Over Full Length 8.000±, in.	Remarks
			Location	No.			
19	25.12 lb/ft	Atmospheric Pressure with Sunshade	LL	8 & 1	0.001	+0.024	
			UR	7 & 2	0.006	+0.010	
			LR	6 & 3	0.014	+0.032	No. 6 Rail Loaded to 6,400 lb at Station 30
			UL	5 & 4	0.008	−0.010	
20			LL	8 & 1	0.004	+0.025	
			UR	7 & 2	0.005	+0.002	
			LR	6 & 3	0.018	+0.035	No. 5 Rail Loaded to 6,400 lb at Station 30
			UL	5 & 4	0.010	−0.014	
21			LL	8 & 1	0	+0.023	
			UR	7 & 2	0.007	+0.009	
			LR	6 & 3	0.015	+0.045	No. 6 Rail Loaded to 6,400 lb at Station 60
			UL	5 & 4	0.008	−0.011	
22			LL	8 & 1	0.005	+0.030	
			UR	7 & 2	0.009	+0.002	
			LR	6 & 3	0.011	+0.039	No. 5 Rail Loaded to 6,400 lb at Station 60
			UL	5 & 4	0.007	−0.019	
23			LL	8 & 1	0.002	+0.021	
			UR	7 & 2	0.012	−0.002	
			LR	6 & 3	0.014	>+0.020	No. 6 Rail Loaded to 6,400 lb at Station 80
			UL	5 & 4	0.008	−0.009	
24			LL	8 & 1	0	+0.013	
			UR	7 & 2	0.006	−0.005	
			LR	6 & 3	0.019	+0.040	No. 5 Rail Loaded to 6,400 lb at Station 80
			UL	5 & 4	0.011	−0.019	
25	48.7 lb/ft Rails 9 & 10 All others 25.12 lb/ft	Atmospheric Pressure with Sunshade	LL	8 & 1	0.003	+0.028	
			UR	7 & 2	0.001	+0.013	
			LR	9 & 3	0	+0.039	No. 9 Rail Loaded to 6,400 lb at Station 30
			UL	10 & 4	0.013	−0.008	
26			LL	8 & 1	0.002	+0.024	
			UR	7 & 2	0.007	+0.007	
			LR	9 & 3	0.006	+0.053	No. 10 Rail Loaded to 6,400 lb at Station 30
			UL	10 & 4	0.014	−0.000	
27			LL	8 & 1	0.002	+0.022	
			UR	7 & 2	0.004	+0.004	
			LR	9 & 3	0.004	+0.037	No. 9 Rail Loaded to 6,400 lb at Station 80
			UL	10 & 4	0.011	−0.009	

Table A-2. Continued

Item No.	Rail Configuration	Test Condition	Rails		Measured End Misalignment Maximum, in.	Rail Spacing Over Full Length 8.000±, in.	Remarks
			Location	No.			
28	48.7 lb/ft Rails 9 & 10 All Others 25.12 lb/ft	Atmospheric Pressure with Sunshade	LL	8 & 1	0.008	+0.024	
			UR	7 & 2	0.010	−0.009	
			LR	9 & 3	0.007	+0.026	No. 10 Rail Loaded to 6,400 lb at Station 60
			UL	10 & 4	0.018	−0.017	
29			LL	8 & 1	0.004	+0.022	
			UR	7 & 2	0.002	+0.007	
			LR	9 & 3	0.003	+0.021	No. 9 Rail Loaded to 6,400 lb at Station 90
			UL	10 & 4	0.016	−0.009	
30			LL	8 & 1	0.001	+0.037	
			UR	7 & 2	0.002	+0.009	
			LR	9 & 3	0.008	+0.030	No. 10 Rail Loaded to 6,400 lb at Station 90
			UL	10 & 4	0.023	−0.001	
31			LL	8 & 1	0.006	+0.017	
			UR	7 & 2	0.008	+0.004	
			LR	9 & 3	0.011	+0.005	
			UL	10 & 4	0.012	−0.014	
32		Vacuum with Sunshade	LL	8 & 1	0.004	+0.013	
			UR	7 & 2	0.001	−0.002	
			LR	9 & 3	0.007	−0.003	
			UL	10 & 4	0.011	−0.017	
33		15 psig with Sunshade	LL	8 & 1	0.005	+0.013	
			UR	7 & 2	0.003	+0.001	
			LR	9 & 3	0.008	−0.009	
			UL	10 & 4	0.008	−0.024	
34		Atmospheric Pressure Top Heated 30 deg Approximate	LL	8 & 1	0.002	+0.019	
			UR	7 & 2	0	+0.003	
			LR	9 & 3	0.014	+0.006	
			UL	10 & 4	0.012	−0.004	
35		Vacuum Top Heated 30 deg Approximate	LL	8 & 1	0	+0.024	
			UR	7 & 2	0.006	+0.005	
			LR	9 & 3	0.005	+0.009	
			UL	10 & 4	0.012	−0.009	
36		15 psig Top Heated 30 deg Approximate	LL	8 & 1	0.001	+0.009	
			UR	7 & 2	0	−0.007	
			LR	9 & 3	0.003	+0.010	
			UL	10 & 4	>0.001	−0.012	

Table A-2. Concluded

Item No.	Rail Configuration	Test Condition	Rails		Measured End Misalignment Maximum, in.	Rail Spacing Over Full Length 8.000±, in.	Remarks
			Location	No.			
37	48.7 lb/ft Rails 9 & 10 All Others 25.12 lb/ft	Atmospheric Pressure with Sunshade Support at Center	LL	8 & 1	0	+0.016	
			UR	7 & 2	0.007	−0.001	
			LR	9 & 3	0.013	+0.004	
			UL	10 & 4	0.018	−0.008	
38		Vacuum with Sunshade Support at Center	LL	8 & 1	0.005	+0.014	
			UR	7 & 2	0	+0.000	
			LR	9 & 3	0.012	+0.015	
			UL	10 & 4	0.018	−0.016	
39		15 psig with Sunshade Support at Center	LL	8 & 1	0	+0.015	
			UR	7 & 2	0.003	−0.006	
			LR	9 & 3	0.009	>+0.004	
			UL	10 & 4	>0.014	−0.014	
40		Atmospheric Pressure Top Heated 30 deg Approximate Support at Center	LL	8 & 1	0.003	+0.016	
			UR	7 & 2	0.005	−0.002	
			LR	9 & 3	>0.007	+0.005	
			UL	10 & 4	>0.003	−0.010	
41		Vacuum Top Heated 30 deg Approximate Support at Center	LL	8 & 1	0	+0.014	
			UR	7 & 2	0.007	+0.004	
			LR	9 & 3	0.003	+0.004	
			UL	10 & 4	>0.005	−0.018	
42		15 psig Top Heated 30 deg Approximate Support at Center	LL	8 & 1	0.008	+0.008	
			UR	7 & 2	0.008	+0.000	
			LR	9 & 3	>0.004	+0.001	
			UL	10 & 4	>0.007	−0.012	
43		Atmospheric Pressure with Sunshade with Penetrations in Vessel	LL	8 & 1	0.001	+0.013	
			UR	7 & 2	0	+0.000	
			LR	9 & 3	0.011	+0.011	
			UL	10 & 4	0.013	−0.013	
44		Vacuum with Sunshade with Penetrations in Vessel	LL	8 & 1	0	+0.021	
			UR	7 & 2	0.001	+0.011	
			LR	9 & 3	0.012	+0.018	
			UL	10 & 4	>0.012	−0.010	
45		15 psig with Sunshade with Penetrations in Vessel	LL	8 & 1	0.003	+0.028	
			UR	7 & 2	0.006	+0.005	
			LR	9 & 3	0.008	+0.020	
			UL	10 & 4	0.009	−0.008	

Table A-3. Displacements Due to Test Conditions

Item No.	Rail Config.	Reference Condition	Rails		Vacuum With Sunshade				15 psig With Sunshade											
					Station, in.				Station, in.				Station, in.				Station, in.			
			Location	No.	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.26
1	25.12 lb/ft	Atmospheric Pressure With Sunshade	LL	8,1	0	0.007	-0.007	0	0.003	0.004	-0.009	0								
			UR	7,2	0.002	0.012	0.015	0.003	-0.002	0.006	0.002	-0.009								
			LR	6,3	0.004	0.037	0.020	0	0.006	0.029	0.015	0								
			UL	5,4	0.022	0	-0.003	0.021	0.005	-0.004	0.002	0.005								
2	25.12 lb/ft	Atmospheric Pressure With Sunshade, Rail Supports at Center	LL	8,1	0.005	0.004	-0.004	0	0	0.001	-0.002	0.006								
			UR	7,2	0.017	-0.009	-0.015	0.028	-0.004	-0.004	-0.012	0.036								
			LR	6,3	0.003	-0.008	-0.004	-0.007	0.003	0.008	0.005	0								
			UL	5,4	-0.012	0.031	0.014	-0.020	0	0.040	0.022	-0.016								
3	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure With Sunshade	LL	8,1	0.006	0.010	0.008	0.007	0.007	0.012	0.011	0.004								
			UR	7,2	0.003	-0.010	-0.005	-0.003	0.002	-0.006	0.003	0.004								
			LR	9,3	0.007	0.005	0.006	0.001	0.009	0.012	0.012	0.003								
			UL	10,4	-0.011	-0.010	-0.006	-0.009	-0.006	-0.010	-0.003	-0.009								
4	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure With Sunshade, Rail Supports at Center	LL	8,1	0.007	0.010	0.009	0.008	0.006	0.017	0.011	0.012								
			UR	7,2	0.001	-0.006	0	0.001	0.004	0.003	0.006	0.014								
			LR	9,3	-0.009	0.012	0.008	0.006	0.007	0.011	0.010	0.011								
			UL	10,4	0	0.002	0.001	0.004	0.001	>0.003	0.004	0.006								

Table A-3. Continued

Item No.	Rail Config.	Reference Condition	Rails		Atmospheric Pressure, ΔT ≅ 30 deg				Vacuum, ΔT ≅ 30 deg				15 psig, ΔT ≅ 30 deg							
					Station, in.				Station, in.				Station, in.				Station, in.			
			Location	No.	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67
4	25.12 lb/ft	Atmospheric Pressure With Sunshade	LL	8,1	-0.003	-0.009	0.010	0.005	0.016	0.033	0.032	0.039	0.007	0.032	0.034	0.050				
			UR	7,2	-0.005	-0.010	-0.012	0	-0.007	-0.031	-0.035	-0.037	-0.010	-0.035	-0.039	-0.052				
			LR	6,3	0.002	0.010	0.006	-0.014	-0.009	-0.016	-0.021	-0.053	-0.015	-0.022	-0.028	>-0.053				
			UL	5,4	0.001	-0.011	-0.008	-0.011	0.015	0.020	0.022	>0.042	0.012	0.011	0.013	> 0.042				
5	25.12 lb/ft	Atmospheric Pressure With Sunshade, Rail Supports at Center	LL	8,1	0.002	0.012	0.006	0	0.002	0.005	-0.002	0	0	0.005	0.003	-0.004				
			UR	7,2	-0.020	0.009	0.002	-0.002	0.013	-0.008	-0.011	-0.019	0.014	-0.004	-0.019	-0.014				
			LR	6,3	0.002	0.014	0.009	-0.012	0.003	0.017	0.009	-0.016	0	0.008	0.005	-0.026				
			UL	5,4	0.019	0.005	0.003	-0.018	-0.004	0.035	0.019	-0.028	-0.015	0.038	0.013	-0.021				
6	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure With Sunshade	LL	8,1	0.005	0.007	-0.001	0.011	0.011	0.017	0.011	0.021	0.013	0.032	0.025	0.044				
			UR	7,2	-0.002	0.008	0	-0.003	0.003	0.022	0.008	—	0.007	0.025	0.017	0.020				
			LR	9,3	0	0.008	0.005	0	0.012	0.012	0.018	0.010	0.012	0.019	0.027	0.036				
			UL	10,4	-0.002	0.007	0.007	0.009	0.008	0.016	0.016	—	0.009	>0.017	0.028	0.031				
7	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure With Sunshade, Rail Supports at Center	LL	8,1	0.012	0.025	0.023	0.046	0.013	0.025	0.020	0.032	0.012	0.025	0.028	0.041				
			UR	7,2	0.010	0.029	0.029	0.013	0.006	0.027	0.025	0.013	0.001	0.020	0.033	0.014				
			LR	9,3	0.009	>0.030	0.028	0.027	0.012	0.028	0.030	0.027	0.010	>0.030	0.031	0.032				
			UL	10,4	0.010	>0.014	0.024	0.013	0.009	>0.014	0.022	0.007	0.009	>0.014	0.020	0.011				

Table A-3. Continued

Item No.	Rail Config.	Reference Condition	Rails		Vacuum				15 psig											
					Station, in.				Station, in.				Station, in.				Station, in.			
			Location	No.	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67
8	25.12 lb/ft	Atmospheric Pressure Insulated	LL	8,1	0	0.006	0.006	0.003	0	0.004	0.010	0.009								
			UR	7,2	0.003	-0.002	0	-0.003	0.003	0.003	0.003	0.006								
			LR	6,3	-0.004	0.002	0.002	-0.006	0	0.007	0.002	-0.006								
			UL	5,4	-0.001	-0.001	-0.005	-0.001	0.004	0.005	0.002	0.006								
9	25.12 lb/ft	Atmospheric Pressure Insulated, Support at Center	LL	8,1	0	0.011	0.011	0.016	0.008	0.015	0.015	0.018								
			UR	7,2	0.005	0.005	0.001	0.005	0.008	0.009	0.002	0.014								
			LR	6,3	0	0.003	-0.001	-0.008	-0.002	0.005	0.001	0								
			UL	5,4	0.004	0.004	-0.001	-0.001	0.003	0.003	-0.002	-0.001								
10	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure With Sunshade, (Penetrations in Shell)	LL	8,1	0.001	0.002	0.001	0.002	0	0.005	0.007	-0.001								
			UR	7,2	0.004	0.011	0.012	0.014	0.005	0.003	0.009	0.019								
			LR	9,3	0.002	0.007	0.006	0.011	0.001	0.004	0.007	0.017								
			UL	10,4	0.005	>0.004	0.005	0.019	0.006	0.003	0.007	0.018								

Table A-3. Concluded

Item No.	Rail Config.	Reference Condition	Rails		LR Loaded (Rail No. 6)				UL Loaded (Rail No. 5)				LR Loaded (Rail No. 9)				UL Loaded (Rail No. 10)			
					Station, in.				Station, in.				Station, in.				Station, in.			
			Location	No.	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67	4.25	115.71	124.25	223.67
11	25.12 lb/ft	Atmospheric Pressure, Rail Loaded at Station 30	LL	8,1	0.003	-0.002	0.002	-0.001	0	-0.003	0	-0.003								
			UR	7,2	-0.001	0	0	0.004	-0.003	-0.002	0	0								
			LR	6,3	-0.005	-0.002	0.001	-0.002	-0.002	0.002	-0.001	0.003								
			UL	5,4	-0.002	-0.001	-0.002	-0.003	0.013	0.005	0.002	0								
12	25.12 lb/ft	Atmospheric Pressure, Rail Loaded at Station 60	LL	8,1	0	-0.003	-0.002	-0.002	0.002	0.003	0.004	-0.001								
			UR	7,2	0	0.004	-0.002	0.002	-0.006	-0.003	0	-0.004								
			LR	6,3	-0.003	-0.001	0	0.006	-0.001	0	0.008	0.001								
			UL	5,4	-0.001	-0.004	0	-0.001	0.008	0.006	0.003	0								
13	25.12 lb/ft	Atmospheric Pressure, Rail Loaded at Station 90	LL	8,1	0.003	0	-0.003	-0.002	0.009	0.002	0	0								
			UR	7,2	0.008	0.003	0	0	-0.001	-0.005	0.007	0.005								
			LR	6,3	-0.003	-0.006	-0.001	0.004	-0.010	0.001	0.002	0.002								
			UL	5,4	0.003	-0.003	-0.002	-0.008	0	0.005	0.004	0.008								
14	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure, Rail Loaded at Station 30	LL	8,1									-0.032	0.004	-0.002	0	-0.003	0.001	0.002	0
			UR	7,2									0.002	-0.001	0	-0.002	-0.007	0.001	0	0.002
			LR	9,3									-0.039	0	0	0	-0.001	0.003	0	0
			UL	10,4									-0.003	-0.003	-0.003	-0.006	0.012	0.002	0.002	0
15	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure, Rail Loaded at Station 60	LL	8,1									0	0.004	0.001	0.004	0.017	-0.007	0.002	0
			UR	7,2									0.003	-0.002	-0.002	0.001	-0.005	-0.001	-0.006	-0.001
			LR	9,3									-0.005	-0.002	-0.002	0.001	0.018	-0.003	-0.002	0.003
			UL	10,4									-0.004	-0.004	0	0	0.006	0.002	0.002	0
16	Rails No. 9 and 10 48.7 lb/ft All Others 25.12 lb/ft	Atmospheric Pressure, Rail Loaded at Station 90	LL	8,1									0	0	0	0	0	-0.001	-0.001	0
			UR	7,2									0	0	-0.002	0.001	-0.003	-0.001	0	-0.001
			LR	9,3									-0.002	-0.005	0.002	0	-0.001	0.002	-0.001	0.006
			UL	10,4									-0.005	0.003	-0.001	0	0.003	0.013	0.001	0.007

Table A-4. Test Measurements for Typical Section of a Prototype of a Proposed Reentry Vehicle Ground Test Facility

Item No	Configuration	Scope Instrument Reading in Station 4 25	32 12	59 98	87 85	115 71	124 25	149 11	173 96	198 82	223 67	231 00	Remarks
A	Repeatability												
	a. With Centerline Guide (No Pressure)												
	1. Lower Right Rails 6	+0.004	+0.010	+0.016	+0.024	+0.034							
	Lower Left Rails 8	+0.004	+0.009	+0.018	+0.025	+0.037							Temperature = 92°F, 1:12 pm Sun Shining, No Sunshade Reference Datum 1
	Upper Right Rails 7	+0.007	+0.018	+0.025	+0.033	+0.038							
	Upper Left Rails 5	-0.007	+0.005	+0.012	+0.019	+0.025							
	Lift Out Tube Section												Lift Straight Up, Move Laterally and Axially and Re-Install
	2. Lower Right Rails 6	+0.003	+0.008	+0.017	+0.024	+0.033							
	Lower Left Rails 8	+0.003	+0.008	+0.015	+0.022	+0.032							Temperature = 94°F, 1:40 pm Sun Shining, No Sunshade Reference Datum 1
	Upper Right Rails 7	+0.006	+0.016	+0.023	+0.028	+0.037							
	Upper Left Rails 5	-0.007	+0.006	+0.012	+0.020	+0.027							
	Lift Out Tube Section												Lift Straight Up, Move Laterally and Axially and Re-Install
	3. Lower Right Rails 6	+0.004	+0.008	+0.014	+0.022	+0.031							
	Lower Left Rails 8	+0.005	+0.010	+0.017	+0.024	+0.031							Temperature, 94°F, 2:02 pm Sun Shining, No Sunshade Reference Datum 1
	Upper Right Rails 7	+0.010	+0.019	+0.026	+0.032	+0.037							
	Upper Left Rails 5	-0.008	+0.003	+0.010	+0.012	+0.016							
	b. Without Centerline Guide (No Pressure)												
	1. Lower Right Rails 6	+0.008	+0.009	+0.009	+0.015	+0.022							
	Lower Left Rails 8	-0.003	0	+0.005	+0.011	+0.018							Temperature = 78°F, 7:37 am Sun Shining, No Sunshade Reference Datum 2
	Upper Right Rails 7	0	+0.007	+0.014	+0.020	+0.025							
	Upper Left Rails 5	0	+0.003	+0.004	+0.009	+0.012							
	Lift Out Tube Section												Lift Straight Up, Move Laterally and Axially and Re-Install

Table A-4. Continued

Item No.	Configuration	Scope Instrument Reading in Station										Remarks
		4 25	32.12	59.98	87.85	115 71	124.25	149 11	173 96	198 82	223 67	231 00	
A	2. Lower Right Rails 6	+0.012	+0.014	+0.018	+0.024	+0.033							
	Lower Left Rails 8	-0.002	+0.003	+0.009	+0.015	+0.023							Temperature = 84°F, 8:45 am Sun Shining, No Sunshade Reference Datum 2
	Upper Right Rails 7	+0.004	+0.015	+0.019	+0.027	+0.030							
	Upper Left Rails 5	+0.002	+0.009	+0.015	+0.020	+0.026							
	Lift Out Tube Section												Lift Straight Up, Move Laterally and Axially and Re-Install
	3. Lower Right Rails 6	+0.013	+0.015	+0.018	+0.023	+0.030							
	Lower Left Rails 8	0	+0.004	+0.010	+0.016	+0.024							Temperature = 85°F, 9:05 am Sun Shining, No Sunshade Reference Datum 2
	Upper Right Rails 7	+0.004	+0.016	+0.019	+0.027	+0.030							
	Upper Left Rails 5	+0.003	+0.010	+0.013	+0.019	+0.024							
B	Modified I-Beam Rail (25.12 lb/ft)												
	a. Atmospheric Pressure with Sunshade												
	Lower Left Rails 8, 1	0	-0.006	-0.008	-0.013	-0.020	-0.010	-0.005	0	0	0	0	
	Lower Right Rails 6, 3	0	-0.008	-0.008	-0.009	-0.011	-0.007	-0.008	0	0	0	0	Temperature = 92°F, 10:10 am Sun Shining, with Sunshade Reference Datum 3
	Upper Left Rails 5, 4	-0.012	-0.004	-0.006	-0.015	-0.020	-0.014	-0.011	-0.002	0	-0.009	-0.005	
	Upper Right Rails 7, 2	-0.008	-0.001	0	0	-0.006	-0.006	0	-0.008	-0.011	-0.016	-0.012	
	b. Vacuum with Sunshade (29 in. Hg)												
	Lower Left Rails 8, 1	0	-0.005	-0.006	-0.013	-0.013	-0.017	-0.011	-0.003	0	0	+0.003	Temperature = 84°F, 3:04 pm, Cloudy with Sunshade, Reference Datum 3
	Lower Right Rails 6, 3	+0.004	+0.007	+0.013	-0.016	+0.026	+0.013	+0.004	+0.004	0	0	-0.006	
	Upper Left Rails 5, 4	+0.010	0	-0.005	-0.012	-0.020	-0.011	-0.008	0	0	+0.012	+0.015	Temperature = 90°F, 2:06 pm, Overcast with Sunshade, Reference Datum 3
	Upper Right Rails 7, 2	-0.006	-0.005	0	+0.002	+0.006	+0.009	0	-0.005	-0.007	-0.013	-0.012	
	c. Pressurized with Sunshade (15 psig)												
	Lower Left Rails 8, 1	+0.003	-0.004	-0.010	-0.014	-0.016	-0.019	-0.012	-0.004	-0.004	0	0	Temperature = 83°F, Sun Shining with Sunshade, Reference Datum 4
	Lower Right Rails 6, 3	+0.006	+0.007	+0.011	+0.012	+0.016	+0.008	+0.002	0	-0.005	0	-0.004	
	Upper Left Rails 5, 4	-0.007	-0.004	-0.008	-0.015	-0.024	-0.012	-0.012	-0.004	0	-0.004	-0.016	Temperature = 98°F, 1:00 pm, with Sunshade Reference Datum 3
	Upper Right Rails 7, 2	-0.010	-0.012	-0.004	0	0	-0.004	0	-0.009	-0.011	-0.025	-0.026	

Table A-4. Continued

Item No.	Configuration	Scope Instrument Reading, in Station 4.25	32 12	59 98	87 85	115 71	124 25	149 11	173 96	198 82	223 67	231 00	Remarks
B	d. Top Heated (ΔT ≅ 30°F) Atmospheric Pressure												
	Lower Left Rails 8, 1	-0.003	-0.005	-0.007	-0.009	-0.011	-0.010	-0.010	-0.011	-0.006	-0.003	-0.004	Temperature = 93°F, 11:39 am, Sun Shining, with Sunshade, Reference Datum 4
	Lower Right Rails 6, 3	+0.002	+0.006	+0.010	+0.020	+0.026	+0.010	+0.005	0	0	-0.014	-0.011	
	Upper Left Rails 5, 4	+0.010	-0.003	-0.009	-0.014	-0.022	-0.013	-0.005	0	+0.006	+0.014	+0.020	Temperature = 93°F, 11:58 am, Sun Shining, with Sunshade, Reference Datum 4
	Upper Right Rails 7, 2	-0.009	-0.006	0	+0.003	+0.006	+0.007	+0.003	0	0	0	0	
	e. Top Heated (ΔT ≅ 30°F) Vacuum (29 in. Hg)												
	Lower Left Rails 8, 1	+0.016	+0.008	+0.010	+0.012	+0.013	+0.012	+0.014	+0.021	+0.029	+0.031	+0.033	Temperature = 97°F, 2:20 pm, Sun Shining, with Sunshade, Reference Datum 4
	Lower Right Rails 6, 3	-0.009	-0.014	-0.012	-0.007	0	-0.017	-0.030	-0.041	-0.049	->0.053	->0.053	
	Upper Left Rails 5, 4	+0.024	+0.019	+0.017	+0.013	+0.009	+0.017	+0.029	+0.049	+>0.053	+>0.053	+>0.053	Temperature = 95°F, 1:50 pm, Sun Shining, with Sunshade, Reference Datum 4
	Upper Right Rails 7, 2	-0.011	-0.015	-0.016	-0.016	-0.015	-0.016	-0.021	-0.030	-0.036	-0.037	-0.040	
	f. Top Heated (ΔT ≅ 30°F) Pressurized (15 PSIG)												
	Lower Left Rails 8, 1	+0.007	+0.008	+0.011	+0.014	+0.012	+0.014	+0.017	+0.028	+0.034	+0.042	+0.043	Temperature = 98°F, Sun Shining, with Sunshade, Reference Datum 4
	Lower Right Rails 6, 3	-0.015	-0.014	-0.014	-0.009	-0.006	-0.024	-0.029	-0.045	-0.052	->0.053	->0.053	
	Upper Left Rails 5, 4	+0.021	+0.013	+0.009	+0.004	0	+0.008	+0.020	+0.029	+0.050	+>0.053	+>0.053	Temperature = 94°F, Sun Shining, with Sunshade, Reference Datum 4
	Upper Right Rails 7, 2	-0.014	-0.017	-0.018	-0.025	-0.019	-0.020	-0.026	-0.034	-0.047	-0.052	-0.051	
C	Modified I-Beam Rail 25.12 lb/ft Supported at Center												
	a. Atmospheric Pressure with Sunshade												
	Lower Left Rails 8, 1	0	0	-0.004	-0.007	-0.011	-0.009	-0.005	-0.004	0	0	+0.004	Temperature = 82°F, 8:23 am, Sun Shining, with Sunshade, Reference Datum 5
	Lower Right Rails 6, 3	0	+0.005	+0.006	+0.014	+0.014	+0.004	+0.004	0	0	0	0	
	Upper Left Rails 5, 4	+0.004	0	-0.006	-0.012	-0.018	-0.008	-0.008	0	0	-0.004	-0.010	
	Upper Right Rails 7, 2	-0.006	-0.008	0	0	+0.004	+0.008	0	-0.007	-0.014	-0.019	-0.015	

Table A-4. Continued

Item No.	Configuration	Scope Instrument Reading in Station										Remarks
		4 25	32 12	59 98	87 85	115 71	124.25	149.11	173 96	198 82	223 67	231 00	
C	b. Vacuum with Sunshade (28 in. Hg)												
	Lower Left Rails 8, 1	+0.005	0	-0.007	-0.007	-0.007	-0.013	-0.007	-0.003	-0.004	0	0	Temperature = 93°F, 1:15 am, Sun Shining with Sunshade, Reference Datum 5
	Lower Right Rails 6, 3	+0.003	+0.006	+0.012	+0.018	+0.022	+0.008	+0.004	0	0	-0.007	-0.009	
	Upper Left Rails 5, 4	-0.008	+0.002	+0.005	+0.011	+0.013	+0.006	+0.003	-0.002	-0.011	-0.024	-0.024	Temperature = 96°F, 12:45 am, Sun Shining with Sunshade, Reference Datum 5
	Upper Right Rails 7, 2	+0.011	+0.005	0	0	-0.005	-0.007	-0.004	0	+0.011	+0.009	+0.018	
	c. Pressurized with Sunshade (15 psig)												
	Lower Left Rails 8, 1	0	0	-0.003	-0.007	-0.010	-0.011	-0.007	0	0	+0.008	+0.009	Temperature = 90°F, 10:05 am, Sun Shining with Sunshade, Reference Datum 5
	Lower Right Rails 6, 3	+0.003	+0.008	+0.010	+0.016	+0.022	+0.009	+0.005	0	0	0	0	
	Upper Left Rails 5, 4	+0.004	+0.007	-0.010	-0.015	+0.022	+0.014	+0.011	0	-0.015	-0.020	-0.034	Temperature = 91°F, 11:48 am, Sun Shining with Sunshade Reference Datum 5
	Upper Right Rails 7, 2	-0.010	-0.010	+0.006	+0.003	0	-0.004	0	+0.009	+0.010	+0.017	+0.019	
	d. Top Heated (ΔT = 30°F) Atmospheric Pressure												
	Lower Left Rails 8, 1	+0.002	0	0	-0.004	-0.004	-0.011	-0.004	0	0	0	0	Temperature = 80°F, Sun Shining, with Sunshade, Reference Datum 6
	Lower Right Rails 6, 3	+0.002	+0.011	+0.018	+0.022	+0.036	+0.021	+0.009	+0.005	0	-0.006	-0.004	
	Upper Left Rails 5, 4	+0.008	+0.005	+0.012	+0.018	+0.027	+0.016	+0.008	0	0	-0.018	-0.018	Temperature = 88°F, 10:01 am, Sun Shining with Sunshade, Reference Datum 6
	Upper Right Rails 7, 2	-0.011	+0.009	+0.012	+0.005	0	-0.005	0	0	+0.015	+0.008	+0.010	
	e. Top Heated (ΔT = 30°F) Vacuum (27 in. Hg)												
	Lower Left Rails 8, 1	+0.002	0	-0.003	-0.003	-0.006	-0.011	-0.008	-0.008	-0.004	0	-0.007	Temperature = 98°F, 1:51 pm, Sun Shining, with Sunshade, Reference Datum 5
	Lower Right Rails 6, 3	+0.003	+0.007	+0.013	+0.019	+0.031	+0.013	+0.004	0	-0.002	-0.016	-0.026	
	Upper Left Rails 5, 4	-0.010	0	+0.006	+0.013	+0.017	+0.011	0	-0.008	-0.017	-0.032	-0.038	Temperature = 94°F, 2:15 pm, Sun Shining, with Sunshade, Reference Datum 5
	Upper Right Rails 7, 2	+0.007	+0.006	0	-0.002	-0.004	-0.003	-0.002	0	0	0	0	

Table A-4. Continued

Item No	Configuration	Scope Instrument Reading, in Station 4.25	32 12	59 98	87 85	115.71	124.25	149.11	173 96	198 82	223 67	231 00	Remarks
C	f. Top Heated (ΔT ≈ 30°F) Pressure (15 psig)												
	Lower Left Rails 8, 1	0	-0.004	-0.001	0	-0.006	-0.006	-0.006	-0.002	0	-0.004	0	Temperature = 98°F, 3:12 pm, Sun Shining, with Sunshade, Reference Datum 5
	Lower Right Rails 6, 3	0	+0.002	+0.011	+0.014	+0.022	+0.009	0	-0.011	-0.014	-0.026	-0.038	
	Upper Left Rails 5, 4	-0.011	0	+0.007	+0.020	+0.020	+0.005	0	0	-0.013	-0.025	-0.026	Temperature = 102°F, 2:41 pm, Sun Shining, with Sunshade, Reference Datum 5
	Upper Right Rails 7, 2	+0.008	+0.007	0	0	0	-0.011	-0.002	0	0	+0.005	+0.011	
D	Modified I-Beam Rail 25.12 lb/ft												
	a. Insulated, Vacuum (28 in. Hg)												
	Lower Left Rails 8, 1	0	-0.005	-0.009	-0.009	-0.014	-0.017	-0.009	-0.009	0	0	0	Temperature = 83°F, 9:40 am, Shell Temperature Top = 86°, Side = 84°, and Bottom = 83°, Reference Datum 7
	Lower Right Rails 6, 3	-0.004	0	+0.003	+0.009	+0.017	+0.009	+0.002	0	-0.003	-0.005	-0.004	
	Upper Left Rails 5, 4	-0.016	-0.008	0	+0.006	+0.012	+0.002	0	-0.009	-0.017	-0.018	-0.025	Temperature = 80°F, 9:11 am, Shell Temperature Top = 85°, Side = 83°, and Bottom = 80°, Reference Datum 7
	Upper Right Rails 7, 2	+0.009	+0.004	0	-0.004	-0.011	-0.010	-0.006	0	+0.006	+0.010	+0.010	
	b. Insulated, Pressurized (15 psig)												
	Lower Left Rails 8, 1	0	-0.005	-0.007	-0.009	-0.016	-0.013	-0.010	-0.005	0	+0.006	+0.011	Temperature = 84°F, 10:12 am, Shell Temperature Top = 88°, Side = 86°, and Bottom = 85°, Reference Datum 7
	Lower Right Rails 6, 3	0	+0.003	+0.005	+0.012	+0.022	+0.009	+0.006	0	0	-0.006	0	
	Upper Left Rails 5, 4	-0.011	0	+0.005	+0.011	+0.018	+0.009	+0.002	0	-0.007	-0.011	-0.014	Temperature = 88°F, Shell Temperature Top = 89°F, Side = 87°F, and Bottom = 86°F, Reference Datum 7
	Upper Right Rails 7, 2	+0.009	+0.010	+0.003	0	-0.006	-0.007	-0.004	+0.004	+0.012	+0.019	+0.020	
	c. Insulated, Vacuum, Support at Center (27 in. Hg)												
	Lower Left Rails 8, 1	0	-0.002	-0.005	-0.005	-0.009	-0.012	-0.006	0	+0.010	+0.013	+0.018	Temperature = 89°F, 1:15 pm, Shell Temperature Top = 92°, Side = 90°, and Bottom = 88°, Reference Datum 7
	Lower Right Rails 6, 3	0	+0.001	+0.005	+0.014	+0.018	+0.006	0	0	-0.004	-0.008	-0.017	
	Upper Left Rails 5, 4	-0.011	-0.005	0	+0.009	+0.017	+0.006	0	-0.007	-0.010	-0.018	-0.024	Temperature = 86°F, 12:52 pm, Shell Temperature Top = 92°, Side = 89°, and Bottom = 88°, Reference Datum 7
	Upper Right Rails 7, 2	+0.011	+0.010	0	-0.003	-0.004	-0.009	0	+0.004	+0.010	+0.018	+0.019	

Table A-4. Continued

Item No.	Configuration	Scope Instrument Reading, in Station 4.25	32 12	59.98	87.65	115 71	124.25	149.11	173.96	198.82	223.67	231 00	Remarks
D	d. Insulated, Pressurized, (15 psig) Support at Center												
	Lower Left Rails 8, 1	+0.008	0	0	−0.004	−0.005	−0.008	0	0	+0.009	+0.015	+0.016	Temperature = 88°F, 1:43 pm, Shell Temperature, Top − 93°, Side − 91°, and Bottom − 90°
	Lower Right Rails 6, 3	−0.002	0	+0.005	+0.013	+0.020	+0.008	+0.004	0	0	0	0	
	Upper Left Rails 5, 4	−0.012	−0.004	0	+0.008	+0.016	+0.005	0	0	−0.006	−0.018	−0.021	Temperature = 86°F, 2:12 pm, Shell Temperature, Top − 93°, Side − 91°, and Bottom − 90°
	Upper Right Rails 7, 2	+0.014	+0.010	+0.004	0	0	−0.008	0	+0.011	+0.022	+0.027	+0.028	
E	Special I-Shape 48.7 lb/ft Rails 9 & 10 Only												
	a. Atmospheric Pressure with Sunshade												
	Lower Right Rails 9, 3	0	+0.009	+0.017	+0.027	+0.031	+0.020	+0.011	+0.008	0	0	0	Temperature = 72°F, 8:43 am Overcast with Sunshade, Reference Datum 21
	Lower Left Rails 8, 1	0	−0.005	−0.010	−0.015	−0.017	−0.011	−0.014	−0.004	0	0	0	
	Upper Right Rails 7, 2	+0.013	+0.009	0	0	−0.008	0	0	0	+0.006	+0.017	+0.006	
	Upper Left Rails 10, 4	+0.002	+0.012	+0.019	+0.025	+0.036	+0.024	+0.013	+0.007	0	−0.009	−0.014	
	b. Vacuum with Sunshade (28 in. Hg)												
	Lower Right Rails 9, 3	+0.007	+0.021	+0.031	+0.038	+0.043	+0.036	+0.036	+0.026	+0.019	+0.017	+0.015	Temperature = 87°F, 1:41 pm Overcast, with Sunshade, Reference Datum 23
	Lower Left Rails 8, 1	+0.006	+0.004	+0.003	−0.002	−0.007	−0.003	0	+0.009	+0.018	+0.024	+0.026	
	Upper Right Rails 7, 2	+0.019	+0.012	+0.010	0	−0.004	−0.005	0	+0.009	+0.017	+0.024	+0.026	
	Upper Left Rails 10, 4	−0.005	+0.009	+0.018	+0.026	+0.040	+0.029	+0.019	+0.009	+0.003	0	0	
	c. Pressurized with Sunshade (15 psig)												
	Lower Right Rails 9, 3	+0.009	+0.023	+0.036	+0.042	+0.050	+0.042	+0.040	+0.027	+0.023	+0.019	+0.019	Temperature = 87°F, 1:41 pm Overcast, with Sunshade, Reference Datum 23
	Lower Left Rails 8, 1	+0.007	+0.004	0	−0.004	−0.005	0	0	+0.011	+0.016	+0.021	+0.027	
	Upper Right Rails 7, 2	+0.018	+0.017	+0.012	+0.009	0	+0.003	+0.013	+0.012	+0.024	+0.031	+0.029	
	Upper Left Rails 10, 4	0	+0.010	+0.017	+0.030	+0.040	+0.032	+0.016	+0.017	+0.009	0	0	

Table A-4. Continued

Item No	Configuration	Scope Instrument Reading in Station											Remarks
		4 25	32 12	59 98	87 85	115.71	124 25	149.11	173.96	198 82	223 67	231 00	
E	d. Top Heated (ΔT ≅ 30°F) Atmospheric Pressure												
	Lower Right Rails 9, 3	0	+0.017	+0.025	+0.034	+0.039	+0.025	+0.020	+0.014	+0.004	0	+0.004	Temperature = 83°F, 10:00 am Overcast, with Sunshade Reference Datum 21
	Lower Left Rails 8, 1	+0.005	−0.003	−0.005	−0.007	−0.010	−0.012	−0.012	−0.003	+0.003	+0.011	+0.009	
	Upper Right Rails 7, 2	+0.011	+0.014	+0.011	+0.012	0	0	0	+0.011	+0.014	+0.014	+0.018	
	Upper Left Rails 10, 4	0	+0.014	+0.028	+0.031	+0.043	+0.031	+0.021	+0.011	+0.004	0	0	
	e. Top Heated (ΔT ≅ 30°F) Vacuum (28 in. Hg)												
	Lower Right Rails 9, 3	+0.012	+0.017	+0.031	+0.042	+0.043	+0.038	+0.036	+0.028	+0.017	+0.010	+0.011	Temperature = 88°F, 1:07 pm, Slight Overcast, with Sunshade Reference Datum 21
	Lower Left Rails 8, 1	+0.011	+0.006	0	0	0	0	0	+0.012	+0.013	+0.021	+0.020	
	Upper Right Rails 7, 2	+0.016	+0.018	+0.015	+0.013	+0.014	+0.008	+0.024	+0.027	Target Hung Up			
	Upper Left Rails 10, 4	+0.010	+0.019	+0.029	+0.042	+0.052	+0.040	+0.033	+0.019				
	f. Top Heated (ΔT ≅ 30°F) Pressure (15 psig)												
	Lower Right Rails 9, 3	+0.012	+0.021	+0.036	+0.040	+0.050	+0.047	+0.041	+0.044	+0.035	+0.034	+0.031	Temperature = 104°F, 1:35 pm Slight Overcast with Sunshade Reference Datum 22
	Lower Left Rails 8, 1	+0.013	+0.009	+0.015	+0.017	+0.015	+0.014	+0.021	+0.023	+0.035	+0.044	+0.044	
	Upper Right Rails 7, 2	+0.020	+0.014	+0.014	+0.013	+0.017	+0.017	+0.030	+0.029	+0.032	+0.037	+0.048	
	Upper Left Rails 10, 4	+0.011	+0.024	+0.035	+0.049	+0.053	+0.052	+0.051	+0.044	+0.033	+0.022	+0.022	
F	Special I-Shape 48.7 lb/ft Rails 9 & 10 Only Supported at Center												
	a. Atmospheric Pressure with Sunshade												
	Lower Right Rails 9, 3	+0.005	+0.017	+0.027	+0.037	+0.046	+0.033	+0.027	+0.026	+0.018	+0.016	+0.017	Temperature = 94°F, 9:54 am Sun Shining, with Sunshade Reference Datum 22
	Lower Left Rails 8, 1	+0.006	+0.004	0	0	0	0	+0.012	+0.019	+0.029	+0.033	+0.039	
	Upper Right Rails 7, 2	+0.022	+0.014	+0.011	+0.011	+0.007	0	+0.014	+0.025	+0.028	+0.037	+0.042	
	Upper Left Rails 10, 4	+0.006	+0.013	+0.029	+0.040	+0.050	+0.034	+0.028	+0.023	+0.016	+0.014	+0.009	

Table A-4. Continued

Item No	Configuration	Scope Instrument Reading, in Station										Remarks
		4 25	32 12	59.98	87.85	115 71	124 25	149 11	173.96	198 82	223.67	231.00	
F	b. Vacuum with Sunshade (28 in. Hg)												
	Lower Right Rails 9, 3	-0.009	+0.028	+0.039	+0.048	+0.050	+0.038	+0.033	+0.029	+0.025	+0.022	+0.017	Temperature - 93°F, 12:26 pm Sun Shining, with Sunshade Reference Datum 23
	Lower Left Rails 8, 1	+0.007	+0.009	+0.004	0	-0.007	-0.002	+0.008	+0.013	+0.018	+0.025	+0.024	
	Upper Right Rails 7, 2	+0.017	+0.012	+0.009	0	0	0	+0.010	+0.015	+0.023	+0.028	+0.038	
	Upper Left Rails 10, 4	+0.006	+0.014	+0.023	+0.034	+0.052	+0.036	+0.026	+0.027	+0.014	+0.013	+0.007	
	c. Pressurized with Sunshade (15 psig)												
	Lower Right Rails 9, 3	+0.007	+0.021	+0.036	+0.046	+0.049	+0.040	+0.038	+0.029	+0.036	+0.027	+0.026	Temperature - 93°F, 12:26 pm Sun Shining, with Sunshade Reference Datum 23
	Lower Left Rails 8, 1	+0.006	+0.007	+0.005	0	0	0	+0.015	+0.017	+0.027	+0.029	+0.030	
	Upper Right Rails 7, 2	+0.020	+0.015	+0.009	+0.007	+0.009	+0.006	+0.009	+0.022	+0.027	+0.041	+0.045	
	Upper Left Rails 10, 4	+0.007	+0.018	+0.031	+0.043	+>0.053	+0.039	+0.032	+0.022	+0.023	+0.015	+0.017	
	d. Top Heated (ΔT ≥ 30°F) Atmospheric Pressure												
	Lower Right Rails 9, 3	+0.009	+0.025	+0.034	+0.047	+>0.053	+0.046	+0.045	+0.036	+0.034	+0.027	+0.027	Temperature - 100°F, 12:03 pm Sun Shining, with Sunshade Reference Datum 22
	Lower Left Rails 8, 1	+0.012	+0.017	+0.014	+0.014	+0.009	+0.012	+0.022	+0.028	+0.036	+0.046	+0.044	
	Upper Right Rails 7, 2	+0.021	+0.026	+0.024	+0.025	+0.025	+0.020	+0.020	+0.035	+0.041	+0.045	+0.048	
	Upper Left Rails 10, 4	+0.010	+0.027	+0.039	+0.050	+>0.053	+0.050	+0.045	+0.036	+0.027	+0.022	+0.017	
	e. Top Heated (ΔT ≥ 30°F) Vacuum (28 in. Hg)												
	Lower Right Rails 9, 3	+0.012	+0.026	+0.037	+0.050	+0.051	+0.048	+0.043	+0.034	+0.034	+0.027	+0.025	Temperature - 100°F, 12:25 pm Sun Shining, with Sunshade Reference Datum 22
	Lower Left Rails 8, 1	+0.013	+0.014	+0.012	+0.012	+0.009	+0.009	+0.015	+0.026	+0.027	+0.032	+0.035	
	Upper Right Rails 7, 2	+0.017	+0.024	+0.024	+0.023	+0.023	+0.016	+0.024	+0.032	+0.040	+0.045	+0.046	
	Upper Left Rails 10, 4	+0.009	+0.030	+0.034	+0.032	+>0.053	+0.048	+0.044	+0.035	+0.027	+0.016	+0.024	

Table A-4. Continued

Item No	Configuration	Scope Instrument Reading, in Station 4 25	32 12	59 98	87 85	115.71	124.25	149 11	173 98	198.82	223 67	231 00	Remarks
F	f. Top Heated (ΔT ≈ 30°F) Pressurized (15 psig)												
	Lower Right Rails 9, 3	+0.010	+0.027	+0.041	+0.047	+>0.053	+0.049	+0.046	+0.040	+0.040	+0.032	+0.034	Temperature = 100°F, 12:05 pm Sun Shining, with Sunshade Reference Datum 22
	Lower Left Rails 8, 1	+0.012	+0.013	+0.014	+0.012	+0.009	+0.017	+0.022	+0.032	+0.042	+0.041	+0 044	
	Upper Right Rails 7, 2	+0.012	+0.016	+0.020	+0.017	+0.016	+0.024	+0.030	+0.038	+0.046	+0.046	+0.045	
	Upper Left Rails 10, 4	+0.009	+0.022	+0.034	+0.048	+>0.053	+0.046	+0.046	+0.034	+0.032	+0.020	+0.022	
G	Effects of Penetrations												
	a. Atmospheric Pressure												
	Lower Right Rails 9, 3	+0.013	+0.021	+0.031	+0.037	+0.039	+0.028	+0.020	+0.016	+0.010	0	0	Temperature = 74°F, 9:15 am Overcast, with Sunshade, Reference Datum 24
	Lower Left Rails 8, 1	−0 008	−0.016	−0.020	−0.022	−0.029	−0.028	−0.022	−0.015	−0.010	−0.006	0	
	Upper Right Rails 7, 2	0	−0.003	−0.007	−0.009	−0.022	−0.022	−0.011	−0.008	0	0	0	
	Upper Left Rails 6, 4	0	+0.014	+0.026	+0.038	+0.049	+0.036	+0.031	+0.022	+0.017	0	0	
	b. Vacuum (27 in. Hg)												
	Lower Right Rails 9, 3	+0.015	+0.028	+0.036	+0.042	+0.046	+0.034	+0.029	+0.022	+0.016	+0.011	+0.014	Temperature = 80°F, 2:06 pm with Sunshade, Reference Datum 24
	Lower Left Rails 8, 1	−0 007	−0.014	−0.018	−0.023	−0.027	−0.027	−0.016	−0.014	−0.013	−0.004	0	
	Upper Right Rails 7, 2	+0 004	0	0	−0.006	−0.011	−0.010	−0.004	0	+0.008	+0.014	+0.014	
	Upper Left Rails 10, 4	+0.005	+0.021	+0.036	+0.046	+>0.053	+0.041	+0.041	+0.036	+0.024	+0.019	+0.007	
	c. Pressure (15 psig)												
	Lower Right Rails 9, 3	+0.014	+0.024	+0.036	+0.040	+0.043	+0.035	+0.026	+0.019	+0.016	+0.017	+0.014	Temperature = 80°F, 12:20 pm with Sunshade, Reference Datum 24
	Lower Left Rails 8, 1	−0.008	−0.013	−0.018	−0.018	−0.024	−0.021	−0.015	−0.014	−0.007	−0.007	0	
	Upper Right Rails 7, 2	+0.005	+0.002	0	0	−0.019	−0.013	−0.002	0	+0.016	+0.019	+0.023	
	Upper Left Rails 10, 4	+0.006	+0.021	+0.034	+0.049	+0.052	+0.043	+0.043	+0.039	+0.029	+0.018	+0.010	
H	a. 48 7 lb/ft Rail Loading Atmospheric Pressure 6,400 lb												
	1. Lower Right Rail Loaded (9) (at Station 30)												
	Lower Right Rails 9, 3	−0 051	−>0.053	−0.048	−0.026	0	0	−0.010	−0.016	−0.010	0	−0.003	Reference Datum 19
	Lower Left Rails 8, 1	+0.015	+0.006	−0.004	−0.009	−0 011	−0.014	−0.010	−0.004	−0.007	0	0	
	Upper Right Rails 7, 2	+0.028	+0.027	+0 024	+0.012	+0.007	+0.006	+0.007	+0.015	+0.017	+0.018	+0.017	
	Upper Left Rails 10, 4	−0.048	−0.029	−0.009	+0.007	+0.019	+0.006	+0.007	+0.007	0	−0.008	−0.007	

Table A-4. Continued

Item No.	Configuration	Scope Instrument Reading, in.										Remarks
		Station										
		4.25	32.12	59.98	87.85	115.71	124.25	149.11	173.96	198.82	223.67	231.00	
H	2. Upper Left Rail Loaded (10) (at Station 30)												
	Lower Right Rails 9, 3	-0.047	-0.041	-0.027	-0.010	+0.006	0	0	-0.006	0	0	0	Reference Datum 20
	Lower Left Rails 8, 1	+0.012	+0.003	-0.005	-0.007	-0.012	-0.010	-0.010	-0.012	-0.004	0	0	
	Upper Right Rails 7, 2	+0.019	+0.022	+0.019	+0.011	+0.007	0	+0.007	+0.010	+0.020	+0.022	+0.023	
	Upper Left Rails 10, 4	-0.037	0	+0.026	+0.027	+0.028	+0.014	+0.010	+0.015	0	0	0	
	3. Lower Right Rail Loaded (9) (at Station 60)			STA 62.5									
	Lower Right Rails 9, 3	-0.045	-0.051	-0.040	-0.030	+0.008	+0.004	+0.006	+0.008	+0.010	+0.007	+0.009	Reference Datum 17
	Lower Left Rails 8, 1	+0.025	+0.020	+0.005	-0.003	-0.004	-0.002	-0.002	0	0	+0.013	+0.013	
	Upper Right Rails 7, 2	+0.039	+0.035	+0.026	+0.019	+0.009	+0.005	+0.009	+0.009	+0.018	+0.017	+0.023	
	Upper Left Rails 10, 4	-0.046	-0.025	-0.004	+0.007	+0.020	+0.009	+0.013	+0.009	+0.004	0	0	
	4. Upper Left Rail Loaded (10) (at Station 60)												
	Lower Right Rails 9, 3	-0.023	-0.022	-0.005	+0.008	+0.017	+0.010	+0.003	+0.001	+0.003	+0.006	0	Reference Datum 18
	Lower Left Rails 8, 1	+0.039	+0.018	+0.011	-0.009	0	+0.008	-0.005	-0.003	0	0	0	
	Upper Right Rails 7, 2	+0.030	+0.026	+0.019	+0.014	+0.010	0	+0.007	+0.016	+0.024	+0.021	+0.022	
	Upper Left Rails 10, 4	-0.040	+0.004	+0.018	+0.034	+0.032	+0.014	+0.011	+0.007	+0.006	0	0	
	5. Lower Right Rail Loaded (9) (at Station 90)				STA 92.5								
	Lower Right Rails 9, 3	-0.038	-0.034	-0.023	-0.014	+0.010	+0.007	+0.007	+0.002	+0.005	+0.009	+0.008	Reference Datum 15
	Lower Left Rails 8, 1	+0.027	+0.019	+0.014	+0.006	0	+0.004	+0.004	+0.006	+0.011	+0.020	+0.018	
	Upper Right Rails 7, 2	+0.039	+0.038	+0.036	+0.020	+0.013	+0.011	+0.020	+0.022	+0.026	+0.032	+0.036	
	Upper Left Rails 10, 4	-0.041	-0.020	-0.008	+0.007	+0.023	+0.007	+0.009	+0.004	0	0	0	

Table A-4. Continued

Item No	Configuration	Scope Instrument Reading, in Station 4 25	32 12	59 98	87 85	115 71	124 25	149 11	173 96	198 82	223 67	231 00	Remarks
H	6. Upper Left Rail Loaded (10) (at Station 90)												
	Lower Right Rails 9, 3	-0.037	-0.016	0	+0.006	+0.012	+0.004	+0.003	+0.006	+0.006	+0.006	+0.005	
	Lower Left Rails 8, 1	+0.026	+0.020	+0.016	0	-0.005	-0.004	-0.003	0	0	+0.010	+0.010	Reference Datum 16
	Upper Right Rails 7, 2	+0.035	+0.035	+0.027	+0.022	+0.021	+0.019	+0.026	+0.033	+0.037	+0.039	+0.031	
	Upper Left Rails 10, 4	-0.036	-0.003	+0.027	+0.036	+0.036	+0.013	+0.019	+0.015	+0.016	+0.012	+0.004	
	b. 25.12 lb/ft Rail Loading Atmospheric Pressure 6,[illegible] lb												
	1 Lower Right Rail Loaded (6) (at Station 30)												
	Lower Right Rails 6, 3	-0.011	-0.033	-0.028	-0.008	+0.022	+0.008	-0.003	-0.007	-0.012	-0.017	-0.017	
	Lower Left Rails 8, 1	-0.013	-0.027	-0.036	-0.041	-0.048	-0.047	-0.045	-0.045	-0.044	-0.036	-0.033	
	Upper Right Rails 7, 2	-0.003	-0.004	-0.012	-0.018	-0.029	-0.035	-0.030	-0.024	-0.023	-0.020	-0.018	Reference Datum 9
	Upper Left Rails 5, 4	-0.021	-0.005	+0.004	+0.015	+0.026	+0.018	+0.011	+0.006	0	-0.013	-0.010	
	2. Upper Left Rail Loaded (5) (at Station 30)												
	Lower Right Rails 6, 3	0	+0.012	+0.018	+0.026	+0.038	+0.020	+0.020	+0.019	+0.017	-0.014	-0.017	
	Lower Left Rails 8, 1	-0.014	-0.019	-0.021	-0.027	-0.031	-0.035	-0.044	-0.046	-0.045	-0.040	-0.035	
	Upper Right Rails 7, 2	-0.005	-0.012	-0.012	-0.022	-0.028	-0.033	-0.028	-0.024	-0.022	-0.015	-0.015	Reference Datum 10
	Upper Left Rails 5, 4	-0.006	+0.040	+0.053	+0.050	+0.032	+0.022	+0.012	+0.012	+0.003	-0.005	-0.008	
	3. Lower Right Rail Loaded (6) (at Station 60)			STA 62.5									
	Lower Right Rails 6, 3	-0.008	-0.038	-0.044	-0.043	+0.015	0	-0.010	-0.016	-0.029	-0.024	-0.032	
	Lower Left Rails 8, 1	-0.018	-0.021	-0.039	-0.043	-0.048	-0.048	-0.046	-0.040	-0.036	-0.033	-0.030	
	Upper Right Rails 7, 2	-0.007	-0.012	-0.016	-0.021	-0.030	-0.037	-0.033	-0.025	-0.021	-0.020	-0.018	Reference Datum 11
	Upper Left Rails 5, 4	-0.019	-0.010	-0.011	+0.002	+0.008	0	-0.005	-0.014	-0.022	-0.034	-0.036	

Table A-4. Concluded

Item No	Configuration	Scope Instrument Reading, in Station 4.25	32 12	59 98	87 85	115 71	124 25	149 11	173 96	198 82	223 67	231 00	Remarks
H	4. Upper Left Rail Loaded (5) (at Station 60)			STA 62.5									
	Lower Right Rails 6, 3	-0.004	-0.006	+0.004	+0.008	+0.014	+0.003	0	-0.012	-0.020	-0 023	-0.023	Reference Datum 12
	Lower Left Rails 8, 1	-0.014	-0.024	-0.035	-0.045	-0.045	-0.050	-0.052	-0.050	-0.051	-0.044	-0.042	
	Upper Right Rails 7, 2	-0.012	-0.019	-0.021	-0.029	-0.038	-0.047	-0.043	-0.035	-0.027	-0 022	-0.012	
	Upper Left Rails 5, 4	-0.011	+0.033	+0.032	+0.039	+0.006	-0.001	-0.007	-0.022	-0.030	-0.036	-0.042	
	5. Lower Right Rail Loaded (6) (at Station 90)				STA 92.5								
	Lower Right Rails 6, 3	-0.040	-?0.053	-?0.053	-0.032	-0.004	-0.018	-0.031	-0.024	-0.035	-0.035	-0.041	Reference Datum 13
	Lower Left Rails 8, 1	+0.030	+0.025	+0.028	+0.006	0	+0.002	+0.006	+0.008	+0.014	+0.019	+0.019	
	Upper Right Rails 7, 2	+0.051	+0.046	+0.046	+0.013	+0.012	0	+0.012	+0.020	+0.025	+0.024	+0.026	
	Upper Left Rails 5, 4	-0.045	-0.041	-0.033	-0.014	-0.008	-0.016	-0.024	-0.025	-0.041	-0.043	-0.030	
	6. Upper Left Rail Loaded (5) (at Station 90)												
	Lower Right Rails 6, 3	-0.039	-0.033	-0.021	-0.007	+0.004	-0.015	-0.028	-0.029	-0.034	-0.025	-0.028	Reference Datum 14
	Lower Left Rails 8, 1	+0.029	+0.027	+0.024	+0.002	0	0	+0.005	+0.008	+0.014	+0.024	+0.023	
	Upper Right Rails 7, 2	+0.039	+0.037	+0.037	+0.007	+0.001	+0.007	0	+0.008	+0.013	+0.024	+0.025	
	Upper Left Rails 5, 4	-0.047	-0.005	+0.012	+0.027	+0.003	+0.014	+0.012	-0.031	-0.033	-0.035	-0.047	

Table A-5. Reference Data for Measurements

Item No	Configuration	Scope Instrument Reading, in Station 4 25	32 12	59 98	87 85	115 71	124 25	149 11	173 96	198.82	223 67	231 00	Remarks
1	Lower Right Rails 6, 3	0	0	0	+0.004	+0.010							Temperature = 83°F, 8:30 am Sun Shining, No Sunshade
	Lower Left Rails 8, 1	0	+0.003	+0.005	+0.005	+0.015							
	Upper Right Rails 7, 2	+0.008	+0.011	+0.017	-0.022	+0.024							
	Upper Left Rails 5, 4	+0.010	-0.004	-0.003	0	+0.002							
2	Lower Right Rails 6, 3	+0.008	+0.009	+0.009	+0.015	+0.022							Temperature = 78°F, 7:37 am Sun Shining, No Sunshade
	Lower Left Rails 8, 1	-0.003	0	+0.005	+0.011	+0.018							
	Upper Right Rails 7, 2	0	+0.007	+0.014	+0.020	+0.025							
	Upper Left Rails 5, 4	0	+0.003	+0.004	+0.009	+0.012							
3	Lower Left Rails 8, 1	0	-0.006	-0.008	-0.013	-0.020	-0.007	-0.005	0	0	0	0	Temperature = 92°F, 10:10 am Sun Shining, with Sunshade
	Lower Right Rails 6, 3	0	-0.008	-0.008	-0.009	-0.011	-0.010	-0.008	0	0	0	0	
	Upper Left Rails 5, 4	-0.012	-0.004	-0.006	-0.015	-0.020	-0.014	-0.011	-0.002	0	-0.009	-0.005	
	Upper Right Rails 7, 2	-0.008	-0.001	0	0	-0.006	-0.006	0	-0.008	-0.011	-0.016	-0.012	
4	Lower Left Rails 8, 1	0	-0.010	-0.015	-0.020	-0.020	-0.020	-0.019	-0.016	-0.006	-0.008	0	Temperature = 72°F, 7:36 am Slight Overcast, with Sunshade
	Lower Right Rails 6, 3	0	+0.003	+0.006	+0.014	+0.016	+0.004	0	0	0	0	0	
	Upper Left Rails 5, 4	+0.009	0	-0.004	-0.009	-0.011	-0.005	-0.003	0	0	+0.011	+0.009	
	Upper Right Rails 7, 2	-0.004	0	+0.005	+0.009	+0.016	+0.019	+0.010	+0.004	0	0	0	
5	Lower Left Rails 8, 1	0	0	-0.004	-0.007	-0.011	-0.009	-0.005	-0.004	0	0	+0.004	Temperature = 82°F, 8:23 am Sun Shining, with Sunshade
	Lower Right Rails 6, 3	0	+0.005	+0.006	+0.014	+0.014	+0.004	+0.004	0	0	0	0	
	Upper Left Rails 5, 4	+0.004	0	-0.006	-0.012	-0.018	-0.008	-0.008	0	0	-0.004	-0 010	
	Upper Right Rails 7, 2	-0.006	-0.008	0	0	+0.004	+0.008	0	-0.007	-0.014	+0.019	+0.015	
6	Lower Left Rails 8, 1	0	-0.008	-0.009	-0.010	-0.016	-0.017	-0.015	-0.010	-0.007	0	0	Temperature = 76°F, 8:08 am Sun Shining, with Sunshade
	Lower Right Rails 6, 3	0	+0.003	+0.009	+0.009	+0.022	+0.012	+0.004	+0.001	+0.003	+0.006	0	
	Upper Left Rails 5, 4	-0.011	0	+0.006	+0.015	+0.022	+0.013	+0.008	+0.008	+0.005	0	0	
	Upper Right Rails 7, 2	+0.009	+0.007	0	0	-0.009	-0.007	-0.005	0	+0.005	+0.010	+0.017	

Table A-5. Continued

Item No	Configuration	Scope Instrument Reading, in Station										Remarks
		4 25	32 12	59 96	87 85	115 71	124 25	149 11	173 96	198 82	223 67	231 00	
7	Lower Left Rails 8, 1	0	−0.008	−0.010	−0.015	−0.020	−0.023	−0.018	−0.014	−0.007	−0.003	0	Temperature = 77°F, 7:57 am Sun Shining, with Sunshade
	Lower Right Rails 6, 3	0	0	+0.005	+0.011	+0.015	+0.007	+0.004	0	0	0	0	
	Upper Left Rails 5, 4	−0.015	−0.006	0	+0.008	+0.013	+0.007	0	−0.004	−0.011	−0.017	−0.016	
	Upper Right Rails 7, 2	+0.006	+0.006	−0.002	−0.002	−0.009	−0.010	−0.005	0	+0.008	+0.013	+0.012	
8	Lower Right Rails 6, 3	0	+0.003	+0.012	+0.023	+0.037	+0.018	+0.012	+0.005	0	0	0	Temperature = 94°F, 12:38 pm Sun Shining, with Sunshade
	Lower Left Rails 8, 1	0	−0.006	−0.012	−0.012	−0.016	−0.019	−0.015	−0.010	−0.007	0	0	
	Upper Right Rails 7, 2	+0.012	+0.002	−0.003	−0.012	−0.015	−0.019	−0.013	−0.007	0	0	0	
	Upper Left Rails 5, 4	−0.015	+0.001	+0.010	+0.024	+0.037	+0.022	+0.024	+0.011	+0.009	+0.003	0	
9	Lower Right Rails 6, 3	−0.006	+0.003	+0.009	+0.015	+0.024	+0.007	+0.003	−0.007	−0.016	−0.019	−0.016	Rail Jack at Station 30
	Lower Left Rails 8, 1	−0.016	−0.027	−0.037	−0.041	−0.046	−0.049	−0.047	−0.041	−0.042	−0.035	−0.031	
	Upper Right Rails 7, 2	−0.002	−0.005	−0.013	−0.013	−0.029	−0.035	−0.029	−0.023	−0.022	−0.024	−0.018	
	Upper Left Rails 5, 4	−0.019	−0.005	+0.004	+0.016	+0.027	+0.020	+0.013	+0.006	0	−0.010	−0.009	
10	Lower Right Rails 6, 3	+0.002	+0.009	+0.018	+0.025	+0.036	+0.021	+0.017	+0.018	+0.014	−0.011	−0.020	Rail Jack at Station 30
	Lower Left Rails 8, 1	−0.014	−0.019	−0.024	−0.026	−0.028	−0.035	−0.040	−0.045	−0.043	−0.037	−0.040	
	Upper Right Rails 7, 2	−0.002	−0.006	−0.010	−0.018	−0.026	−0.033	−0.028	−0.022	−0.018	−0.015	−0.015	
	Upper Left Rails 5, 4	−0.019	−0.001	+0.007	+0.021	+0.027	+0.020	+0.014	+0.003	+0.002	−0.005	−0.008	
11	Lower Right Rails 6, 3	−0.005	−0.001	+0.002	+0.004	+0.016	0	−0.007	−0.015	−0.018	−0.030	−0.031	Rail Jack at Station 60
	Lower Left Rails 8, 1	−0.016	−0.023	−0.036	−0.044	−0.045	−0.046	−0.047	−0.042	−0.038	−0.031	−0.030	
	Upper Right Rails 7, 2	−0.007	−0.013	−0.017	−0.025	−0.034	−0.035	−0.030	−0.027	−0.022	−0.022	−0.019	
	Upper Left Rails 5, 4	−0.018	−0.009	−0.005	+0.006	+0.012	0	−0.003	−0.015	−0.024	−0.033	−0.039	
				STA 62.5									
12	Lower Right Rails 6, 3	−0.003	−0.002	+0.002	+0.008	+0.014	−0.005	−0.005	−0.015	−0.018	−0.024	−0.024	Rail Jack at Station 60
	Lower Left Rails 8, 1	−0.016	−0.025	−0.036	−0.040	−0.048	−0.054	−0.052	−0.047	−0.049	−0.043	−0.043	
	Upper Right Rails 7, 2	−0.006	−0.013	−0.017	−0.024	−0.035	−0.047	−0.038	−0.033	−0.030	−0.018	−0.010	
	Upper Left Rails 5, 4	−0.019	−0.009	−0.015	−0.008	0	−0.004	−0.008	−0.023	−0.031	−0.036	−0.047	

Table A-5. Continued

Item No	Configuration	Scope Instrument Reading, in Station										Remarks
		4.25	32 12	59 98	87 85	115 71	124 25	149 11	173 96	198.82	223 67	231 00	
					STA 92.5								
13	Lower Left Rails 8, 1	+0.027	+0.026	+0.021	+0.004	0	+0.005	+0.004	+0.009	+0.016	+0.021	+0.024	
	Lower Right Rails 6, 3	−0.037	−0.026	−0.027	−0.008	+0.002	−0.017	−0.030	−0.022	−0.026	−0.039	−0.035	Rail Jack at Station 90
	Upper Left Rails 5, 4	−0.048	−0.034	−0.030	−0.013	−0.005	−0.014	−0.020	−0.030	−0.032	−0.035	−0.049	
	Upper Right Rails 7, 2	+0.043	+0.041	+0.037	+0.016	+0.009	0	+0.011	+0.019	+0.019	+0.024	+0.034	
					STA 92.5								
14	Lower Left Rails 8, 1	+0.020	+0.025	0	+0.004	−0.002	0	+0.008	+0.013	+0.020	+0.024	+0.029	
	Lower Right Rails 6, 3	−0.029	−0.030	+0.026	−0.007	+0.003	−0.017	−0.029	−0.032	−0.027	−0.027	−0.029	Rail Jack at Station 90
	Upper Left Rails 5, 4	−0.047	−0.038	−0.031	+0.005	−0.002	+0.010	−0.013	−0.026	−0.037	−0.043	−0.042	
	Upper Right Rails 7, 2	+0.040	+0.041	+0.041	−0.003	+0.006	0	+0.004	+0.021	+0.018	+0.019	+0.024	
					STA 92.5								
15	Lower Left Rails 8, 1	+0.027	+0.019	+0.015	+0.004	0	+0.004	+0.004	+0.008	+0.011	+0.020	+0.022	
	Lower Right Rails 9, 3	−0.036	−0.018	0	+0.008	+0.015	+0.005	+0.007	+0.004	+0.005	+0.009	+0.011	Rail Jack at Station 90
	Upper Left Rails 10, 4	−0.036	−0.022	−0.004	+0.009	+0.020	+0.008	+0.011	+0.009	+0.004	0	0	
	Upper Right Rails 7, 2	+0.039	+0.040	+0.031	+0.019	+0.013	+0.013	+0.019	+0.022	+0.032	+0.031	+0.031	
					STA 92.5								
16	Lower Left Rails 8, 1	+0.026	+0.020	+0.019	0	−0.004	−0.003	−0.004	0	+0.006	+0.010	+0.012	
	Lower Right Rails 9, 3	−0.036	−0.017	0	+0.007	+0.010	+0.005	+0.004	0	+0.004	0	0	Rail Jack at Station 90
	Upper Left Rails 10, 4	−0.039	−0.022	−0.006	+0.014	+0.023	+0.012	+0.017	+0.011	+0.010	+0.005	+0.006	
	Upper Right Rails 7, 2	+0.038	+0.036	+0.030	+0.024	+0.022	+0.019	+0.027	+0.031	+0.034	+0.040	+0.046	
				STA 62.5									
17	Lower Left Rails 8, 1	+0.025	+0.020	0	−0.003	−0.008	−0.003	−0.004	0	+0.002	+0.009	+0.013	
	Lower Right Rails 9, 3	−0.040	−0.024	−0.005	+0.004	+0.010	+0.006	+0.006	+0.006	+0.007	+0.006	+0.005	Rail Jack at Station 60
	Upper Left Rails 10, 4	−0.042	−0.023	−0.004	+0.010	+0.024	+0.009	+0.014	+0.011	+0.008	0	0	
	Upper Right Rails 7, 2	+0.036	+0.033	+0.024	+0.018	+0.011	+0.007	+0.012	+0.014	+0.016	+0.016	+0.020	

Table A-5. Concluded

Item No.	Configuration	Scope Instrument Reading, in.										Remarks
		Station										
		4.25	32 12	59.98	87 85	115.71	124 25	149.11	173.98	198.82	223.67	231.00
				STA 62.5								
18	Lower Left Rails 8, 1	+0.022	+0.018	+0.009	+0.011	+0.007	+0.006	−0.003	−0.004	0	0	0	
	Lower Right Rails 9, 3	−0.041	−0.020	−0.003	+0.011	+0.020	+0.012	+0.004	+0.002	+0.003	+0.003	0	
	Upper Left Rails 10, 4	−0.046	−0.030	−0.007	+0.009	+0.030	+0.012	+0.012	+0.021	+0.004	0	0	Rail Jack at Station 60
	Upper Right Rails 7, 2	+0.035	+0.030	+0.020	+0.016	+0.011	+0.006	+0.011	+0.013	+0.025	+0.022	+0.022	
19	Lower Left Rails 8, 1	+0.047	+0.004	−0.005	−0.004	−0.015	−0.012	−0.010	−0.006	−0.006	0	0	
	Lower Right Rails 9, 3	−0.012	−0.031	−0.019	−0.010	0	0	−0.010	−0.013	−0.014	0	0	
	Upper Left Rails 10, 4	−0.045	−0.024	−0.008	+0.007	+0.022	+0.009	+0.006	+0.007	0	−0.002	−0.010	Rail Jack at Station 30
	Upper Right Rails 7, 2	+0.026	+0.027	+0.022	+0.016	+0.008	+0.006	+0.010	+0.018	+0.017	+0.020	+0.022	
20	Lower Left Rails 8, 1	+0.015	+0.006	−0.004	−0.009	−0.013	−0.012	−0.011	−0.008	−0.013	0	0	
	Lower Right Rails 9, 3	−0.046	−0.029	−0.018	0	+0.003	0	0	0	0	0	0	
	Upper Left Rails 10, 4	−0.049	−0.023	−0.004	+0.010	+0.026	+0.012	+0.013	+0.009	+0.004	0	0	Rail Jack at Station 30
	Upper Right Rails 7, 2	+0.026	+0.026	+0.021	+0.013	+0.006	0	+0.011	+0.015	+0.017	+0.020	+0.026	
21	Lower Left Rails 8, 1	0	−0.005	−0.010	−0.015	−0.017	−0.011	−0.014	−0.004	0	0	0	
	Lower Right Rails 9, 3	0	+0.009	+0.017	+0.027	+0.031	+0.020	+0.011	+0.008	0	0	0	Temperature - 72°F, 8:43 am Overcast, with Sunshade
	Upper Left Rails 10, 4	+0.002	+0.012	+0.019	+0.025	+0.036	+0.024	+0.013	+0.007	0	−0.009	—	
	Upper Right Rails 7, 2	+0.013	+0.009	0	0	−0.008	0	0	0	+0.006	+0.017	—	
22	Lower Left Rails 8, 1	0	−0.009	−0.010	−0.015	−0.016	−0.011	−0.012	0	0	0	0	
	Lower Right Rails 9, 3	0	+0.005	+0.020	+0.026	+0.023	+0.018	+0.012	+0.008	0	0	0	Temperature - 70°F, 8:15 am Sun Shining, with Sunshade
	Upper Left Rails 10, 4	0	+0.012	+0.023	+0.031	+0.039	+0.026	+0.027	+0.019	+0.021	+0.009	+0.010	
	Upper Right Rails 7, 2	+0.011	+0.013	+0.007	0	−0.004	−0.009	+0.011	+0.026	+0.029	+0.032	+0.032	
23	Lower Left Rails 8, 1	0	−0.007	−0.009	−0.013	−0.017	−0.011	−0.007	0	+0.006	+0.017	+0.014	
	Lower Right Rails 9, 3	0	+0.013	+0.024	+0.035	+0.038	+0.030	+0.024	+0.020	+0.014	+0.015	+0.007	Temperature - 85°F, 8:50 am Sun Shining, with Sunshade
	Upper Left Rails 10, 4	+0.006	+0.019	+0.030	+0.038	+0.050	+0.035	+0.031	+0.021	+0.019	+0.009	+0.007	
	Upper Right Rails 7, 2	+0.016	+0.014	+0.014	+0.009	+0.006	0	+0.007	+0.016	+0.022	+0.027	+0.030	
24	Lower Left Rails 8, 1	−0.008	−0.016	−0.020	−0.022	−0.029	−0.028	−0.022	−0.015	−0.010	−0.006	0	
	Lower Right Rails 9, 3	+0.013	+0.021	+0.031	+0.037	+0.039	+0.028	+0.020	+0.016	+0.010	0	0	Temperature - 74°F, 9:15 am Overcast, with Sunshade
	Upper Left Rails 10, 4	0	+0.014	+0.026	+0.038	+0.049	+0.036	+0.031	+0.022	+0.017	0	0	
	Upper Right Rails 7, 2	0	−0.003	−0.007	−0.009	−0.022	−0.022	−0.011	−0.008	0	0	0	